Colour and Colorimetry Multidisciplinary Contributions

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Edited by
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1. COLOUR AND MEASUREMENT / PRODUCTION

What is new in color-difference evaluation? (A tribute to Prof. Claudio Oleari, Universitá degli Studi di Parma, Italy)

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Abstract

We consider the problem of prediction of visually-perceived color differences by human observers with non-defective color vision, starting from objective instrumental measurements of two nearly homogeneous color samples. This is the classical color-difference problem considered by CIE Technical Committees since 1950's but not yet satisfactorily solved. Three main different aspects will be discussed: 1) the need of experimental visual datasets with high reliability; 2) the fundamentals for the development of appropriate color-difference formulas; 3) the use of relevant indices to measure the relationship between visually-perceived and computationally-predicted color differences. While the CIEDE2000 color-difference formula was jointly recommended in 2013-2014 by CIE and ISO to promote uniformity of practice and satisfy industrial needs, this formula is not considered a final satisfactory answer. Currently, three different CIE Technical Committees (TC 1-55, TC 1-63 and TC 1-81) are working on different aspects of the problem of color-difference evaluation. Nowadays, research on color differences continues being relevant because of its connection with the proposal of new color spaces or color appearance models, and the practical usefulness of color-difference formulas in industrial color-quality control and many other applications.

1. Introduction

For two color samples, we can consider the magnitude of the visually-perceived color difference, usually designated as ΔV (from visual difference), and also the color difference computed from instrumental color measurements of the mentioned samples, which is usually designated as ΔE. The specific computation providing ΔE is designated as a "color-difference formula", and modern color-difference formulas take also into account parameters related to the specific illuminating and viewing conditions of the two samples under consideration. It can be said that ΔE is an objective measurement, while ΔV is a subjective measurement (the answer of the human visual system). Obviously, the most important part in the binomial ΔV-ΔE is ΔV. Color scientists interested in this field try to achieve color spaces and color-difference formulas ΔE providing accurate predictions of ΔV, for any pair of color samples under any viewing conditions [1].
An important part of the research carried out in the field of color-difference evaluation was related to the need of successful industrial color-quality control. Thus, it is desired that correct pass/fail decisions can be made automatically from objective color measurements, replacing visual subjective assessments performed by panels of experienced (or naive) observers. In general, color-difference formulas have been widely employed in many different applications related to textiles, automobiles, packaging, graphic arts, cultural heritage, food, agriculture, dentistry,

medicine, etc. [2-12]. Surprisingly, beside the increasing interest of all aspects related to color image, it is relevant to note that the relatively “simple problem” of the color difference perceived by an average human observer for two homogeneous color samples with the same shape and size, and observed under the same illuminating and viewing conditions, has not yet been satisfactorily solved. This paper considers the status-of-the-art of such simple problem, because it can be useful to analyze more complicated situations, such as, for example, the perceived color differences between two complex static or dynamic color images [13-15]. Specifically, in the next sections we will discuss on available color-difference visual datasets and color-difference formulas, and how to measure the merit of a color-difference formula with respect to a given set of experimental visual data. Results achieved by most recently proposed color-difference formulas will be also reported.

2. Methods

2.a. Color-difference visual datasets

Obviously, visual datasets on color differences must be as reliable as possible, because they are the starting point for the development or testing of successful color-difference formulas. Bearing in mind that visual assessments of color differences are essentially subjective, the mentioned reliability imply that experiments must be performed by a relatively high number of observers with tested normal color vision, working under a controlled set of illuminating and viewing conditions using a rigorous methodology. The final goal is to obtain the average and standard deviation of visually-perceived color differences for a large number of color pairs spread in all regions of an approximately uniform color space. Since famous MacAdam’s color matching experiment performed by only one observer [16], many visual datasets with increasing reliability have been reported. To avoid a potential spread of inconsistent results, CIE provided useful guidelines for coordinated research in color-difference evaluation [17, 18], suggesting specific methodologies, the study of a set of 17 color centers, and the use of a set of viewing conditions, considered as the most usual ones in industrial applications, which are known as “reference conditions” (Table 1). As it is well known, perceived color differences depend on viewing conditions [19], and therefore the mentioned CIE guidelines have been useful to produce more consistent visual results in experiments performed at different laboratories.

Illumination:	D65 source
Illuminance:	1000 lx
Observer:	Normal color vision
Background field:	Uniform, neutral gray with L^*=50
Viewing mode:	Object
Sample size:	Greater than 4°
Sample separation:	Direct edge contact
Sample color-difference magnitude:	Lower than 5.0 CIELAB units
Sample structure:	Homogenous (without texture)

Table I. Reference conditions currently suggested by CIE [18] for coordinated color–difference evaluation.

At the end of past century, visual datasets from four different laboratories were considered as acceptably reliable and, after a common visual scaling, they were weighted and put together to produce the so-called COM-dataset (or COM-Weighted dataset) with a total of 11273 color pairs, which was used for the development of last CIE/ISO recommended color-difference formula, CIEDE2000 [20, 21]. This COM-dataset was modified in 2008, after detecting some problems in the use of the original data from one of the four laboratories, which led to the proposal and subsequent use of the so-called COM-corrected dataset [22]. Strictly speaking, combination of color-difference visual datasets from different laboratories should be only possible when the viewing conditions and methodologies in all laboratories were the same, which was not exactly the case for the COM-corrected dataset. If it is decided to produce a combined dataset, particular attention must be paid to the problem of how to manage potential different visual scales used in the different laboratories, because different scaling methods lead to different results [22, 23]. It seems also very convenient to analyze the final combined dataset, for example, by using fuzzy techniques [24], in order to detect/remove potential inconsistent color pairs in the final proposed combined dataset.
After the development of CIEDE2000, CIE TC 1-55 was conscious of the need of new reliable visual datasets, and requested its development and proposal [25]. As a result of this request, some new object-color datasets have been proposed, both, for color pairs in wide [26-30] and very specific regions of the color space [31, 32]. Results achieved from these new visual datasets will be addressed in next section 3. By the moment, we would like also state that CIE is working to improve the access to current reliable visual datasets to all researchers. As mentioned at the beginning of this sub-section, to obtain highly reliable visual experimental data has proved to be an essential part in order to solve many current problems in color-difference evaluation, as well as in other fields of color science [33].

2.b. Color-difference formulas

As summarized by Luo [34], the first color-difference formulas were based on the Munsell system, followed by formulas based on MacAdam's color matching data, and linear (or non-linear) transformations of tristimulus values X,Y,Z. To date, CIE has recommended five color-difference formulas, which are in chronological order: 1) The CIE 1964 U*,V*,W* formula [35], used to define the current CIE color rendering index [36]; 2-3) the CIELUV [37] and CIELAB [38] approximate uniform color spaces and corresponding color-difference formulas, which were jointly recommended in 1976 and have been recently adopted as CIE/ISO standards; 4) the CIE94 color-difference formula [39], which was the first CIE formula to incorporate the influence of illuminating/viewing conditions as parametric factors; 5) the CIEDE2000 color-difference formula, which is also another joint CIE/ISO standard, and the currently recommended color-difference formula [20, 21].
The CIELAB space has been widely accepted, and many successful CIELAB-based color-difference formulas like, for example, CMC [40], BFD [41], CIE94 [39], DIN99d [42], CIEDE2000 [20], and ULAB [43], have been proposed during the past years. After CIEDE2000, researchers have proposed new color-difference formulas based on color spaces other than CIELAB: for example, the CAM02-SCD

and CAM02-UCS formulas [44] based on the CIECAM02 color-appearance model, the OSA-GP [45] and OSA-GP-Euclidean [46] color-difference formulas based on a development of the OSA-UCS color space [47, 48], and the WLab (Waypoint-Lab) color-difference formula based on a perceptually uniform material color equivalency space [49]. While CIELAB seems not to be the best choice, nowadays the best color space to define a successful Euclidean color-difference formula is an open problem. CIE TC 1-55 was constituted to propose a new color space with a Euclidean color-difference formula statistically significant better than CIEDE2000, but the works of this TC concluded stating that no current available color space can achieve this goal. Therefore, unfortunately, from current available visual data it is not possible to recommend a new specific color space for color-difference evaluation [50].

The high number of parameters in some previously mentioned color-difference formulas indicates that experimental results have been probably over-fitted, and researchers claim that the goal of achieving a new appropriate color space with sound physiological bases seems to be lost. It is important to emphasize that color-difference formulas can be used only when two color stimuli with the same shape and size are viewed under the same illuminating/viewing conditions. Otherwise (e.g. stimuli illuminated by two different light sources, or stimuli with different sizes or/and backgrounds, etc.), we must use color appearance models or other specific tools before applying a color-difference formula. This means that it is likely that the problem of color differences can be considered in the future as part of the more general problem of color appearance, or other general problems in current color science like color constancy, etc.

Anyway, industry continues claiming improved color-difference formulas for quality control. For example, modern automotive industry using effect materials is interested in new successful color-difference formulas which can be used for solid and effect (i.e. gonioapparent) materials [5]. In addition, it must be added that in many industrial applications involving color differences it is necessary to consider other appearance attributes of materials in addition to color (e.g. coarseness, glint, texture, etc.). For example, it is generally recognized that different kind of textures may produce relevant changes in visually-perceived color differences [51]. Thus, the concept of “total difference” in place of just “color difference” has been introduced [52], and currently it can be said that the interactions between color and other appearance attributes is an ongoing research topic.

2.c. Performance indices

Different indices have been proposed to measure the goodness of predictions of a set of visual data (ΔV) made by a color-difference formula (ΔE) [53]. While only just one performance index may be not ideal for all situations, CIE TC1-55 is going to recommend [50] the use of the *STRESS* (Standardized Residual Sum of Squares) index [54] from multidimensional scaling for this purpose. The *STRESS* index is defined by next Equations, where ΔV_i and ΔE_i (i=1,…N) are the visual and computed color differences, respectively, for the N color pairs, and F_1 is a scaling factor to put visual and computed color differences on a common scale:

$$STRESS = 100\left(\frac{\sum_{i=1}^{N}\left(\Delta E_i - F_1\ \Delta V_i\right)^2}{\sum_{i=1}^{N} F_1^2 \Delta V_i^2}\right)^{1/2} \quad \text{with} \quad F_1 = \frac{\sum_{i=1}^{N}\Delta E_i^2}{\sum_{i=1}^{N}\Delta E_i \Delta V_i}$$

Among the main advantages of the *STRESS* index, we can mention that it can be used to know whether two color-difference formulas are or are not statistically significant different for a fixed confidence level, and also to compute intra- and inter-observer variability in visual experiments [55]. It must be remembered that measurements of perceived color differences are always subjective, and therefore these measurements have a non-negligible uncertainty which must be taken into account. The accuracy of a color-difference formula can be acceptable when it provides *STRESS* values which are below the intra- and inter-observer variability, measured also as *STRESS* values, because in this situation the use of such color-difference formula is equivalent to the results reported by an average real observer.

3. Results

Figure 1 shows *STRESS* values for the COM-corrected visual dataset, employed at the development of currently recommended color-difference formula CIEDE2000, using 13 different color-difference formulas. Low/high *STRESS* values (always in the range 0-100) mean good/bad performance of a color-difference formula. Fig. 1 shows that CIEDE2000 is the best tested color-difference formula for this specific dataset (lowest *STRESS* = 27.5), as was expected bearing in mind that this formula was developed from this dataset. It can be also added that for the COM-corrected dataset, CIEDE2000 is statistically significant better than any of the 12 remaining color-difference formulas, because of the large number of color pairs in this dataset.

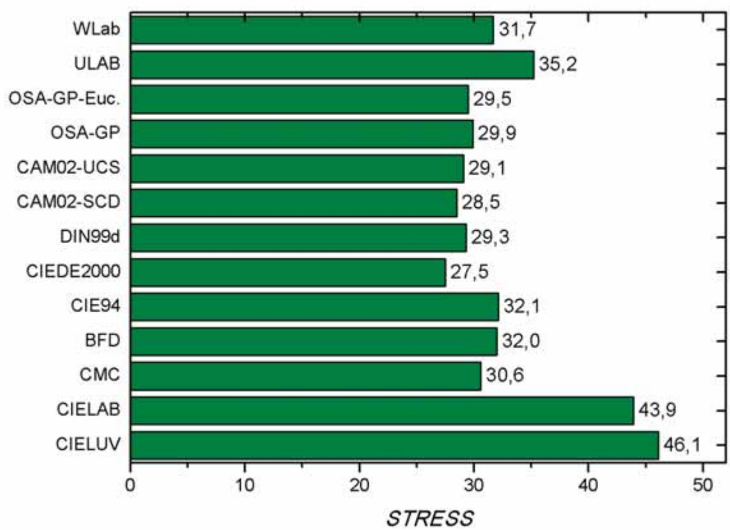

Fig. 1 – *STRESS* values for the COM-corrected visual dataset and 13 color-difference formulas. Small *STRESS* values (always in the range 0-100) mean better performance of a color-difference formula.

However, Fig. 1 also shows that some other recent color-difference formulas achieve *STRESS* results close to those from CIEDE2000. Therefore it is interesting to test what is the situation for other visual datasets developed after the proposal of CIEDE2000. Using the visual datasets in references 26-32, we can conclude that the situation is in part similar to the one in Fig. 1: it is not possible to find color-difference formulas being significantly better than CIEDE2000, with only a few exceptions: the OSA-GP [45], OSA-GP-Euclidean [46], and WLab [49] formulas in the dataset in reference 27, and the WLab formula in the semi-gloss dataset in reference 28. Fig. 2 shows *STRESS* results for 4 most relevant current color-difference formulas and the datasets reported in references 26-32.

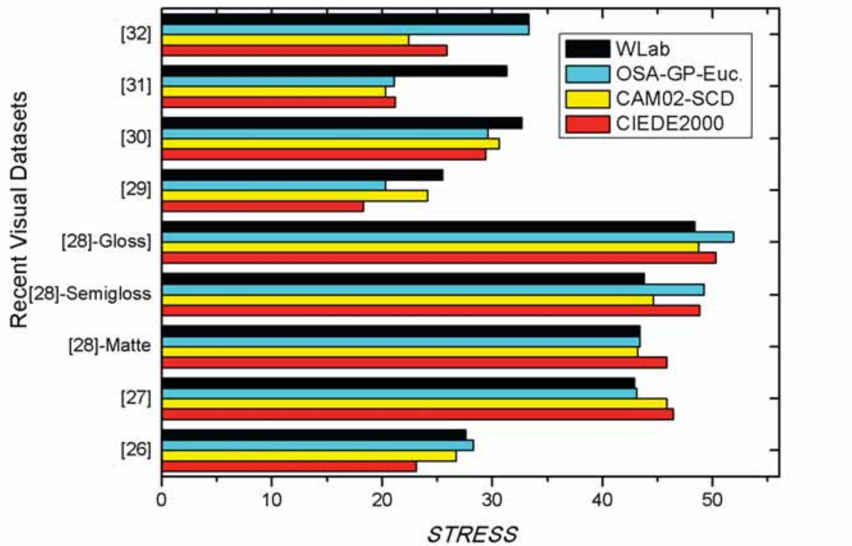

Fig. 2 – *STRESS* values for some visual datasets developed after the proposal of CIEE2000 and 4 most relevant current color-difference formulas. Numbers in the ordinate axis correspond to the references of the visual datasets.

While in Fig. 1 *STRESS* values for best color-difference values were slightly below 30 units, we can note in Fig.2 considerably higher values for some visual datasets. An example of the order of magnitude of *STRESS* values for inter- and intra-observer variability may be the values 24.0 and 21.8, respectively, which were reported in a recent experiment in the black region of color space [32]. Therefore, it can be stated that nowadays in most cases the *STRESS* results achieved by best color-difference formulas are close (but not below) values corresponding to inter- and intra- observer variability, which means that research looking for better color-difference formulas for industrial applications must continue.

CIE TCs 1-63 and 1-81 are currently studying the range of validity of CIEDE2000, which was initially fixed as 0-5 CIELAB units [20, 21], in agreement with reference conditions shown in Table 1. It seems that most color-difference formulas perform considerably worse for very small color differences (below 1.0 CIELAB units, approximately), which is the situation in most color pairs in visual datasets reported in references 27 and 28 (see Fig. 2). It also seems that CIELAB is clearly improved by most current color-difference formulas (see Fig. 1), but this may be not the case in experiments managing very large color differences [56]. In any case, these experiments are not so interesting from the point of view of industrial applications as the ones considering the range 0-5 CIELAB units. It cannot be assumed that the performance of the human visual system is the same for color differences with different magnitudes, as proved, for example, by the proposal of specific color-difference formulas for large color differences [57]. Recently, it has been proposed the use of power functions as a useful tool to improve the performance of most currently available color-difference formulas, in particular for small color differences [58]. Unfortunately, although this approach seems to be accepted by CIE TC 1-81, it just means a compression of computed color differences, not a result related to the performance of the human visual system (e.g. Stevens' law).

4. Conclusions

We have described some of most important advances made in color-difference evaluation in the past 20 years. Unfortunately, no color space with a Euclidean color-difference formula significantly better than CIEDE2000 can be currently proposed from available visual datasets. While different current color-difference formulas may satisfy some industrial needs, research in this filed must continue. It seems clear that this research must not be focused just on the fit of new color-difference formulas from new reliable visual datasets, but a consideration on best color spaces satisfying (among others) the needs of industry in color-difference evaluation. As stated for tristimulus values [59], we think that it can be also said that color differences is an old problem for a new generation.

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Working with the LSh-Color space

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1. Introduction: Saturation and Chroma of a colour

In the field of physiology the terms of saturation and chroma are not used correctly. Many of the physiologists only use the term saturation.
First the difference between chroma and saturation has to be explained. For this we consider a hue triangle (Fig. 1). Such a triangle goes back to Ewald Hering. After him Wilhelm Ostwald and many others worked with triangles and today we find a hue triangle in the Natural Colour System (NCS).
On the right corner of the colour triangle we find the pure colour. This colour is the colour with the greatest chroma. We can add the triangle with lines for the mixtures of white or black and with the pure colour. If we add black to a colour the saturation changes only a little, but if we add white to a colour the saturation decreases. After adding more black to a colour the saturation also decreases and we arrive at a point where we have a coloured black.
The direction which shows the saturation in figure 1 is only an approximation. We cannot draw an exact straight line of saturation in the triangle.

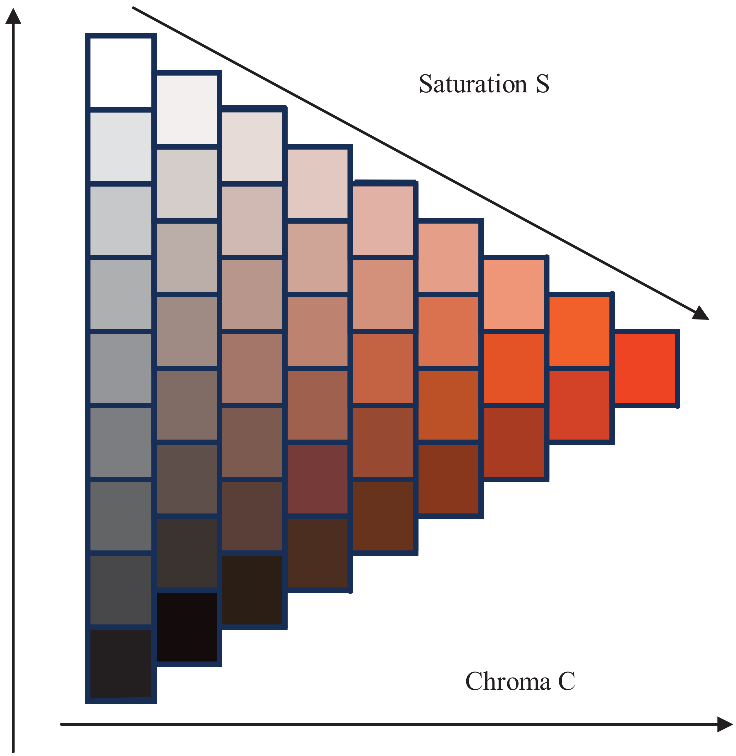


Fig. 1 The terms chroma and Saturation

Since 2008 we have had the possibility to use the LSh-colour space which is based on the saturation of a colour [1]. As I showed 2011 in my habilitation [2] you can get the saturation S^+ with the following formula:

$$S^{+} = \frac{C^{*}_{ab}}{\sqrt{C^{*2}_{ab} + L^{*2}}} \cdot 100\% \qquad [1]$$

In this formula C^*_{ab} ist the Chroma and L^* the Lightness of the colour in the CIELAB system.
This formula is in agreement with a verbal definition by Manfred Richter [3]: Saturation is the proportion of pure chromatic colour in the total colour sensation.
The experimental verification of this formula [1] was done in a habilitation treatise on Ilmenau University. For the experiments the Japanese colour system PCCS has been used. The PCCS system has charts of different saturation but with visually equal hues. The results of the experiment with the PCCS also shows that the saturation S^+ better corresponds with the visual values than the saturation in CIECAM02 [2; 4].

2. LCh-colour space and LSh-colour space

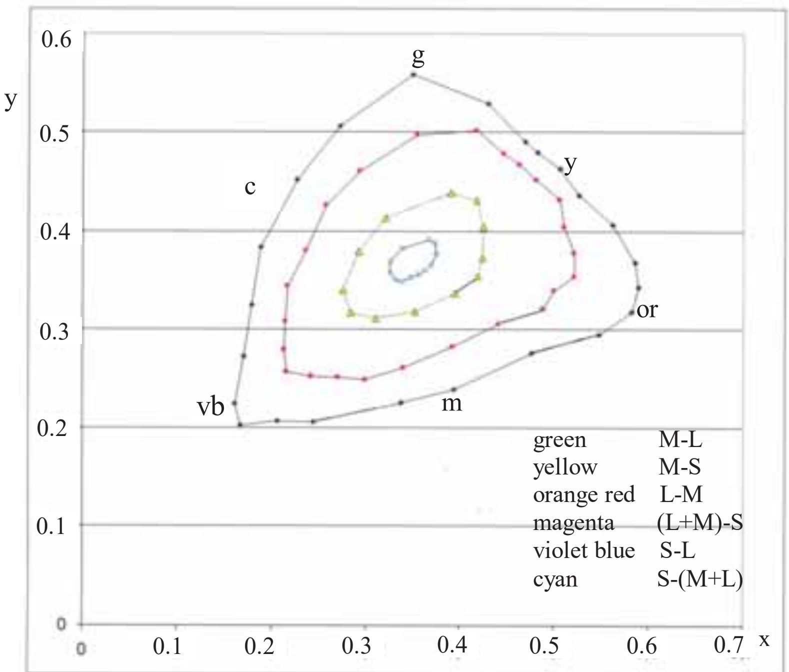
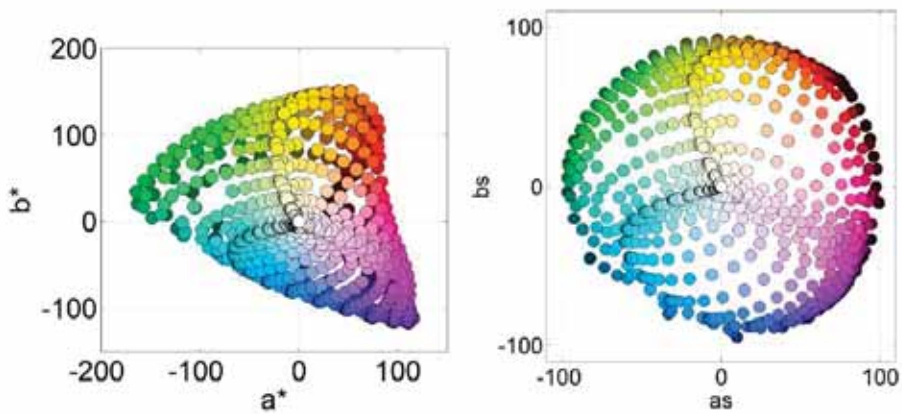


Fig. 2 Lines of equal saturation. We see large distances of these lines by orange red, green and violet blue and smaller distances by magenta, yellow and cyan [5].

In Fig. 2 we see the lines of equal saturation in the xy-system.
These lines of equal saturation have different distances. We find large distances by orange red, green and violet blue and smaller distances by yellow, magenta and cyan. An explanation for the measured effects in saturation lines may be found in the opponent colour cells. Valberg summaries in [6] that six opponent colour cells have been detected: S-L; M-S; (L+M)-S; M-L; L-M; S-(M+L). His calculation of the opponent-colour signals results in three minima and three maxima.

If we take the Rösch [7] colour space (space of the "optimal colours") and transform it into a new space with the axes L,S^+ and h, we get a nearly symmetrical space. It is much more symmetrical than the LCh-space. It can be seen in Fig. 3.



$a_s = S \cdot \cos h_{ab}$ $b_s = S \cdot \sin h_{ab}$

Fig. 3 LCh- colour space and LSh-colour space

In Fig. 4 we see colour charts of two colorants common in the printing industry. From left to right the degree of surface coverage of magenta increases in steps of 10 %. From top to bottom the degree of surface coverage of black increases.
Fig 5 shows the first five series measured values from Fig. 4 and the serie with 80% degree of surface coverage and with 100% black. In Fig. 6 these values have been recalculated into saturation.
In Fig. 6 one can recognise almost vertical lines that correspond to the same degree of surface coverage of magenta. In LCh Colour Space these lines run towards the black point (Fig. 5).

From Figs. 5 and 6 one can recognise that C_{max} is not exactly equal to $S_{max.}$
If you speak with designers you can see that they can agree with this effect.

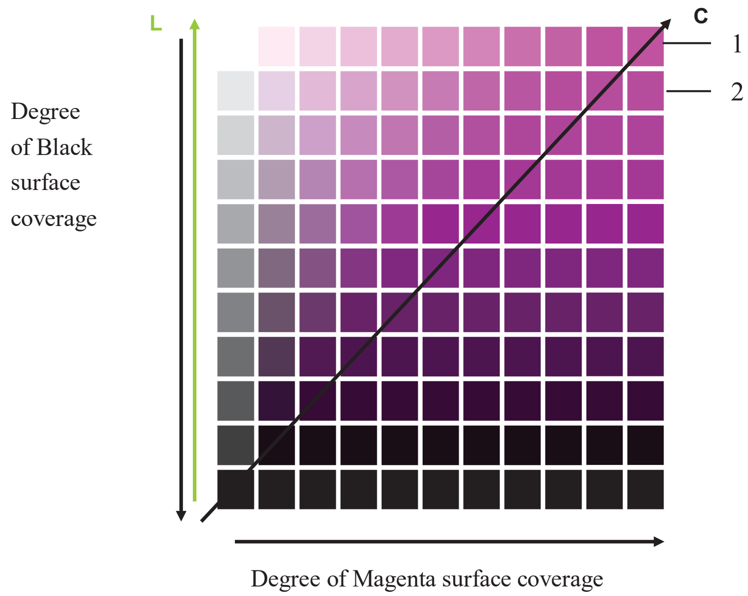


Fig. 4 Combined Print of Magenta and Black depending on degree of surface coverage

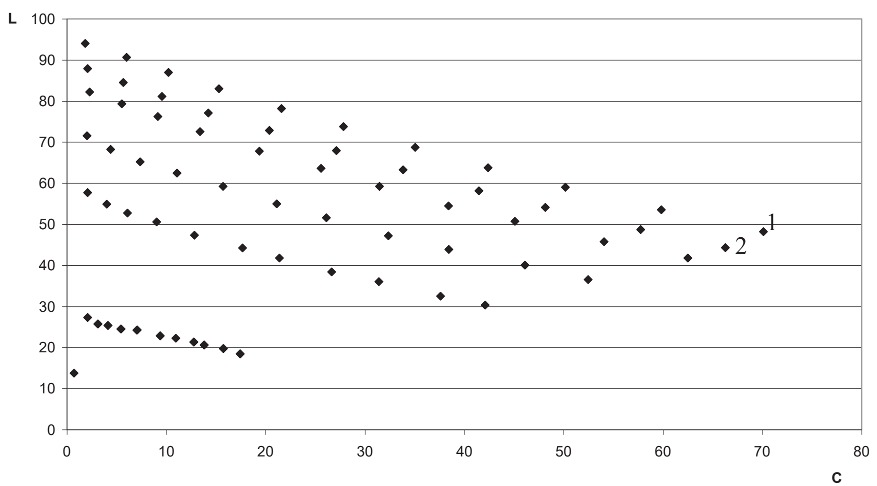


Fig. 5 Magenta level of CIELAB Colour Space: Lightness L depends on Chroma C

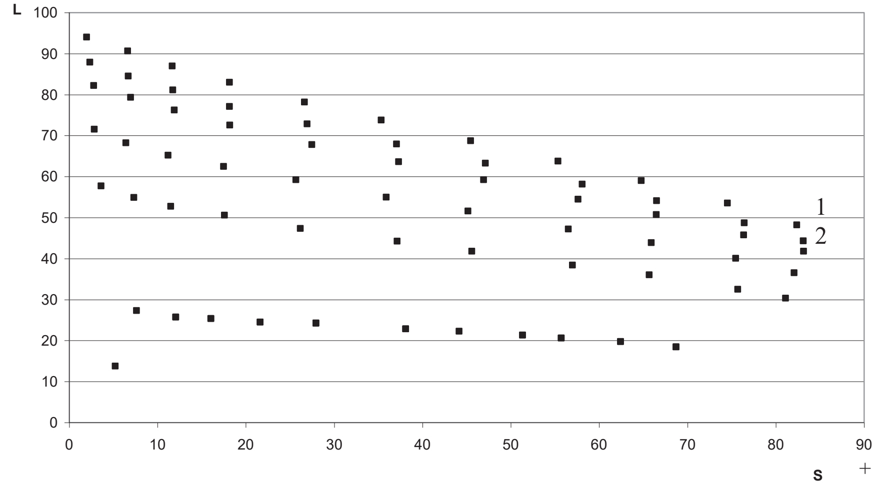


Fig. 6 Magenta level of CIELAB Colour Space: Lightness L depends on Saturation S^+

The LSh-colour space could be of interest for people working in architecture, for designers, for physiologists and for controlling printing.

3. Colour distances in LSh-colour space

The LS^+h colour space also is of interest for calculating colour differences: Colour distances of saturated colours are smaller in the LSh-colour space than in the LCh-colour space.

You can use the LSh-colour space for measuring colour distances ΔE according to the following formula:

$$\Delta E_S = \sqrt{\Delta L^2 + \left(\frac{\Delta a_S}{1+0{,}0115 \cdot S}\right)^2 + \left(\frac{\Delta b_S}{1+0{,}0115 \cdot S}\right)^2}, \qquad [2]$$

with $a_s = S \cdot \cos h_{ab}$

$b_s = S \cdot \sin h_{ab}$

This formula [2] works also by distances greater than ΔE = 5 which the ΔE 2000 did not [8].

4. Using the LSh-colour space

4.1 Example with PCCS Harmonic Cards

In the following table we can compare the values of lightness L, chroma C, and saturation S^+ of four charts. These charts are chosen from the Japanese Colour system PCCS (PCCS Harmonic Cards 201).

	Yellow V8	Red V2	Violett -blue V19	Green V14
h	85,7	25,1	274,8	183,5
L	79,0	45,8	36,2	47,8
C	97,3	67,6	43,1	58,6
S^+	77,6	82,8	76,6	77,5

Tab. 2 Some Charts from PCCS

The PCCS Harmonic Cards are made for the practical use. You can see that the values for the saturation S^+ are $\cong$ 80, but the values for chroma are very different.

4.2 Example from Textile Industry

I would like to give an example for textile industry [9]. There we could use a small colour measurement device including the formula for saturation. The device was originally made for hairdressers and can also be used in other crafts. It is small and works in combination with a personal computer. So you can use it in many practical questions.

The following figure shows blue textiles. These textiles were used in measuring colour authenticity.

Fig. 7 charts after DIN EN ISO 105-B

If you compare the charts you see that the charts 3 and 5 are much more saturated. In the following table we find the measurement values of these charts. You can see that visually perception is in agreement with measured values S^+.

Probe	L	C	S+ [%]	h [°]
1	41,60	46,11	74,25	269,28
2	42,36	47,65	74,74	262,34
3	36,58	50,58	81,03	279,95
4	33,54	31,55	68,52	256,29
5	29,34	41,53	81,67	280,94
6	29,93	27,86	68,14	245,54
7	29,14	26,80	67,68	266,43
8	28,20	22,79	62,86	255,02

Tab. 2 Charts after DIN ISO 105-B

5. Conclusion

With the saturation S we have the possibility to work in a space which is much more symmetric than LCh-colour space and colour distances $\Delta E > 5$ are describable because only small corrections of the colour distance formula are necessary.
The LSh-colour space could be of interst for people working in architecture, for designers, for physiologists and for controlling printing.

Acknowledgments

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Colorimetric characterizations of gonio-apparent surfaces for the development of materials with new visual effects

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1. Introduction

Gonio-apparent surfaces are present in many industrial sectors such as automotive, cosmetics, plastics for consumer electronics, printing and security inks, architectural panels ... They are characterized by large variations of their visual rendering, depending on illumination and observation directions. For this reason the measurement and management of colour quality of such surfaces is a complex problem, which combines technological challenges and human perception issues.

Gonio-apparent colours first enter the market-place in the 1950s in the USA with the use of metal-flake pigments in automotive paints, to create "metallic paint" effect. More recently, other applications have been developed, as for example anticounterfeiting coatings [1]. However, neither standard geometries nor internationally accepted methods for assessing colour variations of gonio-apparent materials are available yet [2].

Our aim is to develop materials with new visual effects, and to precisely control their colour variations with illumination and observation directions. We present colorimetric characterization of titanium anodized samples, that is, titanium samples on which titanium dioxide (TiO_2) is grown at the surface of the sample by electrolysis. This material was shown to display promising features for generating particular visual effects, as it exhibits a wide gamut of structural gonio-apparent colours [3], with applications in architecture and design [4]. Dense layers of TiO_2 on titanium-based substrates have various valuable physical properties that yield numerous industrial applications. For instance, TiO_2 exhibits photocatalytic properties [5] [6], useful for antifogging or surface self-cleaning applications [7] [8]. The properties we are most interested in in this study are, beyond the coloured visual effects, their mechanical and chemical stability. Combined to their versatility in terms of colour gamut and the possibility to adjust their gonio-chromatic character as a function of the surface topography of the substrate (see [28] and section 3.3. below), they make anodised titanium a viable candidate for producing standard samples and reference scales of gonio-apparent metallic or "metallized" surfaces.

In this paper, we will first present a short review of existing instruments for characterizing gonio-apparent materials. After a short description of the device we developed, we will present characterizations of the colour evolution of gonio-apparent titanium anodized samples with illumination and observation directions. The influence of the surface roughness of the samples on the colour evolution is then investigated. We thus demonstrate that it is possible to control the gonioappearence of a material by changing its surface roughness. Although gonioappearence of thin films is a well-known phenomenon, the study of the influence of the roughness of the surface on the colour variations has not been reported in the literature. The present work consists in preliminary characterizations, but simulations are needed to correlate roughness parameters and colour variations.

2. Short review of existing colorimetric characterization methods of gonio-apparent samples

The reflectance of a surface is entirely characterized in the front hemisphere by a function called Bidirectional Reflectance Distribution Function (BRDF). If the spectral variations of the BRDF in the visible spectral range (380 nm to 780 nm) are known, it is then possible to infer the colour variations of the surface in the whole hemisphere. The critical features for such characterizations are the high angular accuracy needed to properly measure the rapid colour variations of highly gonio-apparent samples, as well as the necessary optimization of data acquisition to avoid time and memory-consuming measurements. The general principle of a BRDF measurement consists in illuminating the sample with calibrated light in a particular geometrical configuration and then detecting the light reflected by the sample in another particular geometrical configuration.

Common commercial spectrophotometers dedicated to colour measurements are based on a measurement of the sample reflectance in one particular geometrical configuration. The most common geometries are 0°/45° (or 45°/0°) and d/8° (or 8°/d), where the first character corresponds to the illumination direction and the second to the detection direction. The letter "d" means "diffuse": for d/… geometries, the illumination is brought by an illuminated integrating sphere, for …/d geometries, the detector is placed inside the inner volume of an integrating sphere collecting the light scattered by the sample. Nevertheless, such devices are not fully satisfactory for the characterization of gonio-apparent samples. Alternative devices have been developed, mainly for the characterization of metallic or varnish effects in the automotive industry. These so called "multi-angle spectrophotometers" measure reflected intensities for typically four or five detection angles with a fixed illumination direction, as proposed by DIN 6175-2 [10]. However, it has been demonstrated [9] that multi-angle spectrophotometers, are not sufficient for the characterization of "pearlescent" and interference pigments. BRDF measurements are then necessary for the full characterization of reflected intensities with gonio-apparent materials.

Many BRDF measurement setups are reported in the literature. However, few combine both spectral variations measurements and a sufficiently high angular accuracy to allow the colorimetric characterization of gonio-apparent surfaces. Note that high angular accuracy not only implies a high angular positioning accuracy of illumination and detection arms, but also low angular apertures for both illumination and detection. To clarify future considerations, we remind that the angular resolution of the human eye, considered as diffraction-limited, is about 0.01°. We will now proceed to a non-exhaustive review of existing BRDF-measurement devices that allow spectral characterizations over the visible spectrum. In a first part, we will describe sequential-scanning devices, that is, devices with which each angular position is acquired one after the other (Fig. 1 shows the typical geometry of sequential-scanning devices). In a second part simultaneous-scanning devices will be described.

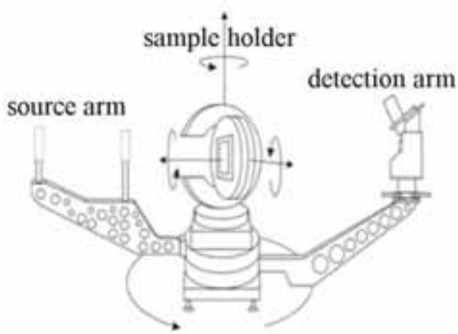

Fig. 1 – Typical geometry of sequential-scanning devices (after [11]).

2.1 Sequential-scanning devices

In 1996, Proctor et al. reported [12] the design and implementation of the STARR high accuracy gonio-spectrophotometer at the National Institute of Standards and Technology (NIST). This device is capable for measuring BRDF as well as BTDF (Bidirectional Transmittance Distribution Function), over a wide spectral range (200 nm to 2500 nm), with an angular resolution of about 0.09° and a spectral bandwidth of about 7 nm. The angular apertures of the illumination and detection arms are not reported by the authors. Only in-plane measurements could be performed with this device, that is, with an observation direction in the plane defined by the incidence direction and the normal to the sample surface. More recently, the NIST has developed a new gonio-spectrophotometer [13] that allows the measurement of the complete BRDF over the spectral range [360 nm – 780 nm], with a spectral resolution of 0.05 nm and an angular resolution of better than 0.01° for each axis. This gonio-spectrophotometer was designed to become the reference BRDF measurement device at NIST, for the characterization of complex surfaces like gonioapparent coatings or retroflective surfaces. Another highly accurate gonio-spectrophotometer has been built in Germany [14]: its spectral range is [250 nm – 1700 nm], with a spectral bandwidth of 3 nm in the visible spectral range. The angular positioning resolution is 0.0002° for the illumination arm and 0.002° for the sample holder, but angular apertures are many orders of magnitude higher: half-angles of 0.32° for the detection and 1.5° for the illumination.

Pointer et al. reported [15] gonio-spectrophotometric measurements of a gonio-apparent Red/Gold ChromaFlair [16] sample, using colour evolutions of the sample in the CIELAB colorspace as well as in the CIE 1931 xy-chromaticity diagram were given. Nevertheless, the gonio-spectrophotometer described by the authors has some limitations: the BRDF of the sample could not be measured in the specular direction (i.e. when the angle between the normal to the sample surface and the illumination direction is equal to the angle between the normal to the sample surface and the detector direction) because of the lack of dynamics of the detector. Moreover the device can only perform in-plane BRDF measurements. The wavelength range of the device is [380 nm – 780 nm], with a spectral bandwidth of 5 nm. The half-angle acceptance of the instrument is 0.5°, with an angular positioning resolution of the detector arm equal to 0.001°. More recently, Leloup et al. reported [17] BSDF (Bidirectional Scatter Distribution Function) measurements of three different ChromaFlair samples. A BSDF measurement consists in both BRDF and BTDF measurements. Their setup allows both reflectance and transmittance measurements. It is composed of a motionless illumination arm with an aperture angle of lower than 2°. The sample holder has two rotational degrees of freedom, one with an angular resolution of 1° and another with a resolution of 1/60°. The detector arm has also two rotational degrees of freedom, both with an angular resolution of 0.001°. The half angular acceptance angle of the detector is 0.9°. The spectral bandwidth of the device is about 4 nm, and the whole visible spectrum can be acquired. Rabal et al. also describe a BSDF measurement device [18]. This device has the particularity to include a beam-splitter, which allows measuring also retro-reflection. The illumination arm is also motionless. The sample holder is a six-axis robot arm, which gives angular uncertainties lower than 0.005°. The detector is placed on a cogwheel, with an angular positioning uncertainty of 0.1°. The smallest field of view of the detector is 0.1°. BSDF can be acquired over the whole visible spectral range, with a bandwidth of 4 nm.

Commercial sequential scanning devices are available [19] [20]. Both devices can measure either BRDF or BTDF. The ARTA accessory of reference [19] has an angular resolution and accuracy of respectively 1/60° and 5/60° for BRTF and BTDF, and can perform spectral measurements over the range [240 nm – 2500 nm]. The REFLET-180 bench of reference [20] has a spectral range of [400 nm – 900 nm]. Its best angular resolution and accuracy are respectively 0.1° and 0.3°. The minimal angular acceptance of the detector is 0.04°.

2.2 Simultaneous-scanning devices

As measurements are time consuming with sequential-scanning devices, other BRDF measurement methods have been proposed, which can acquire multiple angles simultaneously. Specifications about angular resolution are however rarely given for such devices.

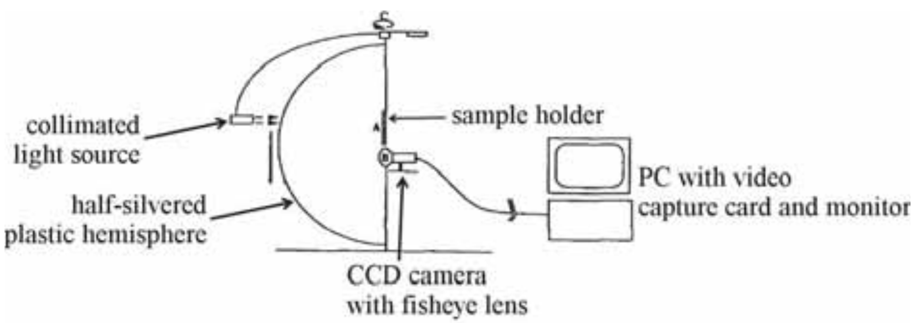

Fig. 2– Schematic diagram of the BRDF measurement device proposed by G. J. Ward [21].

A first proposal for such a device was made in 1992 by G. J. Ward [21]. This device consisted in a hemispherical mirror reflecting light scattered from the sample back into a fisheye lens mounted on a CCD camera (see **Errore. L'origine riferimento non è stata trovata.**). Spectral variations of the BRDF could be measured by inserting filters in front of the white light quartz-halogen source. This device allows measurements of the light reflected from the sample, as well as retroreflected and transmitted light. The limitations of this setup are twofold: reflectance at grazing angles could not be measured, and the optical precision of the mirror was not sufficent to characterize glossy surfaces with sharp specular peaks.

Lu et al. reported BRDF measurements of shot fabric [22], by wrapping the samples around a right-circular cylinder (see Fig. 3). Samples are illuminated by a parallel light source, and the scattered light is collected by a digital camera. The cylinder can be tilted around its centre to collect the BRDF outside the incidence plane. The whole spectral variations of the BRDF are not recorded. But as the camera includes red, green and blue colour filters, it is possible to measure colour variations of the samples.

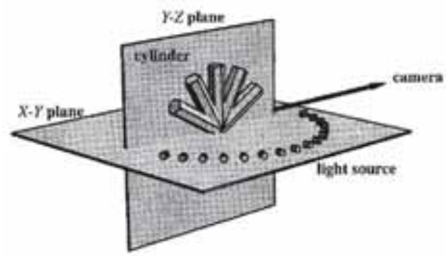

Fig. 3 – Schematic diagram of the experimental apparatus used in reference [22].

Marschner et al. [23] extended the BRDF measurement principle proposed by Lu et al. [22] to a wide class of curved near-convex samples. The method consists in taking a series of photographs of a curved object. Each image captures light reflected from many differently oriented parts of the object. By knowing the object shape, for example with 3D scanning, and the light source position, the photographs can be analysed to determine the object's BRDF. The light source is motionless, while the camera moves, allowing measurements of the full three-dimensional BRDF. The camera CCD sensor has an RGB colour filter array which gives the possibility to measure sample colour variations.

Ren et al. [24] proposed an ingenious system to convert the three dimensional angular distribution of a surface reflectance into a two-dimensional planar image, using a hemi-parabolic mirror (see Fig. 4). The planar image is collected by a CCD camera and goes through a coordinate mapping procedure. The authors claim that measurement of in plane and out of plane reflectance distributions may be realized within two minutes. Nevertheless, the light souce used in this device is a monochromatic laser, meaning that sample colour variations cannot be measured. Besides, the analyzed surface of the sample is fairly small.

More recently, Boher et al. [25] reported the build-up of an optical instrument based on Fourier optics for fast multispectral BRDF characterization. This device allows rapid spectral full BRDF measurements: the detection of light scattered by the sample is detected simultaneously at all angular positions including the illumination direction. The spectral variations are acquired thanks to an automated wheel with 31 band pass filters regularly distributed in the visible spectrum. BRDF measurements, for tens of wavelengths, of various makeup foundation creams have been demonstrated, showing specular and backscattering contributions. Spectral BRDF measurements of LCD display top polarizers have also been carried out in order to characterize the top parasitic reflection of the display. Note that devices based on this principle are commercialised by ELDIM society [26].

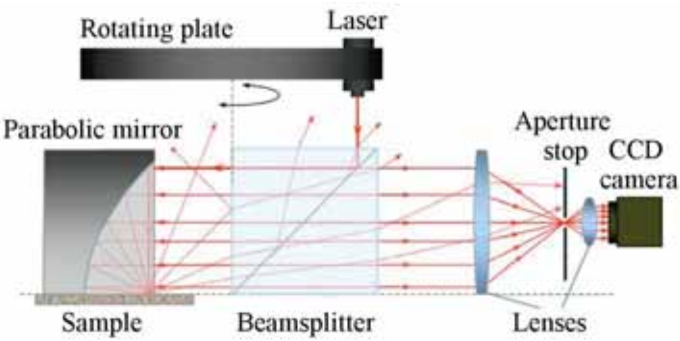

Fig. 4 – Schematic diagram of the BRDF measurement device proposed by Ren et al. [24].

3. Colorimetric characterization of gonio-apparent titanium anodized samples

In the following, we present characterizations of the colour changes of gonio-apparent titanium anodized samples with illumination and observation directions.

3.1 Gonio-spectrophotometer used for the chatacterizations

The device used for the measurements is a sequential-scanning laboratory gonio-spectrophotometer built at Laboratoire Georges Friedel. This device, called OptiMines, is fully described by Matsapey et al. [27]. It is composed of three main sub-systems:

- a rotating illumination arm containing a 50 W fibered halogen lamp which illuminates the sample after being collimated by an optical system,
- a rotating and movable sample holder
- a rotating detection arm containing a second optical system which focusses the light beam reflected by the sample onto a fibered Maya2000 Pro spectrometer

The illumination and detection arms have only one rotational degree of freedom and move in the same plane. The sample holder has two rotational degrees of freedom: it may rotate on itself or tilt around the motion plane of the illumination and detection arms. The sample holder may also be moved back to allow the direct spectrometric measurement of the source.

The key features of this device are its high angular resolution (less than 0.02°) and its low incident light half-divergence and detector's angular half-acceptance (both are equal to 0.1°), which make it very sensitive to rapid angular variations of the spectral reflectance. The effective wavelength range of the gonio-spectrophotometer is [380 nm – 1100 nm], with a spectral bandwidth of 3 nm and a spectral resolution of 0.5 nm. This device has the particularity to combine both small size (the whole setup operates inside a volume of about 1 m x 1 m x 0.6 m) and high angular resolution.

In the paper describing this setup [27], the ability of OptiMines to measure both the BRDF of diffusing materials as well as the colour evolution of glossy gonio-apparent ChromaFlair samples was demonstrated. In the following, we present colorimetric characterizations of gonio-apparent titanium anodized samples. The colour variations around the specular direction are characterized, more specifically the influence of the direction of the incident light on these colour variations on the one hand, and the influence of the surface roughness of the sample on the other.

3.2 Anodized Ti samples

The samples are 3 cm x 4 cm coupons sampled in commercial-grade pure titanium plates (ASTM grade 1 or 2). Two types of grade 2 plates were used: the first one is 1.3 mm thick and has an initial rather rough surface finish before preparation; the second one is smoother, with a thickness of 2 mm. The grade 1 plate is 2 mm thick, with a relatively smooth surface topography.

Different surface preparations have been carried out on the samples as presented in Tab. 1, where the denomination of the various samples is also mentioned. The average roughness parameter R_a [28] indicated in Table I was measured with an optical profiler Wyko NT9100 (ex-Veeco) Bruker Nanoscope™. After degreasing with acetone, the samples are anodized in sulfuric acid 0.5 M, with a galvanostatic regime current of 6 A. The anodizing process is stopped when the cell potential reaches the desired value. This value is taken equal to 10 V, 20 V or 90 V, to generate different oxide layer thicknesses and thus different colours, as the colours are due to an interference phenomenon occurring in the TiO_2 layer [2].

Denomination	Material	Sample thickness (mm)	Initial surface finishing	Surface preparation	R_a (µm)
Series 1	Grade 1	2	smooth	mirror polishing	0.15
Series 2	Grade 2	1.3	rough	no preparation	1.9
Series 3	Grade 2	2	smooth	no preparation	0.33
Series 4	Grade 2	2	smooth	mirror polishing	0.15

Tab. 1 – Materials, surface preparation and denomination of the samples.

Fig. 5presents digital colour pictures of the anodized samples with an observation angle either equal to or different from the incidence angle of light, which respectively corresponds to the “specular” and “out of specular” geometries.
At first sight, we observe that the colour of the samples, for the same anodizing potential, may vary with the surface finish. This phenomenon is especially noticeable for the samples anodized at 90 V, which appear either pink in series 2 in the specular direction or green in series 4 in the same observation conditions. One may also notice that the colour of the 90 V sample in series 1 appears pink in the specular direction, indicating that the anodizing process yields different oxide layer properties on grade 1 or grade 2 metallic plates.
All the samples do not have the same level of gonio-appearance, i.e. the same variation of colour rendering according to the viewing angle. It is more pronounced for the 90 V samples in series 4, whereas the roughest samples (series 2) are almost not gonio-apparent.

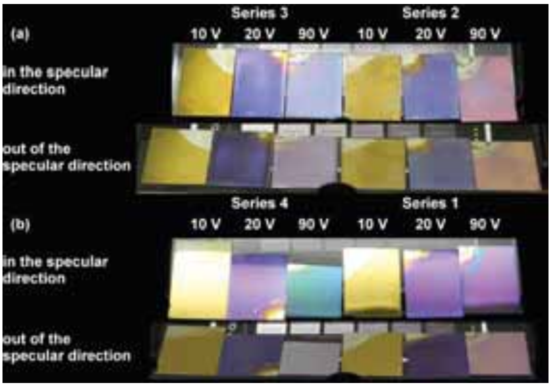

Fig. 5 – Digital colour pictures of the anodized samples of the series 2 and 3 (a) and of the series 1 and 4 (b). The incidence angle of the illuminant source is 45° and the observation angle is either 45° (specular direction) or 70° (out of the specular direction).

3.3 Characterization method for the colour variations

Many parameters may influence the spatial colour variations of the samples. We investigated this influence through many directions and give in this section some examples illustrating its characteristic features. We first study the influence of the surface finishing on the chromatic paths (colour variations) around the specular direction. This is illustrated for an incidence angle of 45°, by two comparisons:

- the first one between the samples anodized at 10 V of series 2 and 3,
- the second one between the samples anodized at 90 V of series 2 and 4.

We may observe that the rougher the surface, the weaker the colour variations in the chromaticity diagram. Focusing on the mirror polished samples, we study the influence of the incidence angle on the chromatic paths around the specular direction. This is illustrated on the sample anodized at 90 V of series 1, with four different incidence angles: 30°, 45°, 60° and 70°. We observe that for grazing incidence angles the the colour variations are weaker. This study also highlights the evolution of the colour in the specular direction for the previously cited angles.

3.4 Results and discussion

In this part, we will represent the colour evolution of the samples, as described above, in the CIE 1931 chromaticity diagram. The rationale for this choice as well as the details of the calculation of the (x, y) chromaticity values from the BRDF values are given elsewhere [29]. We summarize here the most significant results.

The chromatic paths of the samples are first investigated around the specular direction, for an incidence angle of 45°, with respect to the influence of the surface roughness, for two different anodizing potentials, 10 V and 90 V. **Errore. L'origine riferimento non è stata trovata.** shows the colour variations of the samples anodized at 10 V of series 2 and 3 and the samples anodized at 90 V of series 2 and 4, in the CIE-chromaticity diagram around the specular direction. We observe that for smooth or mirror polished surfaces, the saturation of the colour, evaluated here as the distance of the colour to the D65 white point, exhibit higher variations around the specular direction than for "rough" samples. The highest saturation variations occur for the most specular samples (10 V of series 3 and 90 V of series 4). Moreover, for these samples, the most saturated colour are observed in the specular direction, which is consistent with the interferential origin of the colours. In contrast, non-interferential coated surfaces such as metallic plates with thick varnish coating, would display a less saturated colour due to the white light component reflected by the surface of the varnish in the specular direction.

Finally, the fact that the colours of the 10 V samples vary in the chromaticity diagram along almost straight lines passing through the D65 point means that the hue is almost invariant according to the observation angle for all surface roughness conditions. This is however not the case for the 90 V sample of series 4, which is consistent with the qualitative observation of the high gonio-apparent character of this sample, as illustrated in Fig. 5.

In order to check our goniometric colour measurements, we compared, for the samples of series 2, the (x, y) chromaticity values deduced from the goniometric measurements to those deduced from a colorimetrically calibrated picture of the samples. These components are represented, for the 90 V sample, by a blue triangle on **Errore. L'origine riferimento non è stata trovata.**. We may consider that the sample colour caught from the digital picture is in good agreement with the colours deduced from goniometric measurements, given the following limiting factors: the illumination and detection solid angles are different for the gonio-spectrophotometer and in the picture acquisition configuration, and the accuracy of the angular positioning of the camera is limited.

We then characterize the chromatic paths around the specular direction for various incidence angles. **Errore. L'origine riferimento non è stata trovata.** presents this characterization for the series 1 sample anodized at 90 V at incidence angles equal to 30°, 45°, 60° and 70°. For all values, we observe that the colour with the highest saturation is in, or very close to the specular direction. The specular colour evolves from bluish to pinkish when the incidence angle increases, and its saturation decreases. The hue modification reflects the gonio-apparent character of the sample. The decrease of the saturation may be explained by the increase of the Fresnel reflection coefficient of the air/TiO_2 interface which leads to a higher difference of amplitude between interfering light waves. The contrast of the interference fringes thus decreases, giving a spectral BRDF with less pronounced minima and maxima. As the color saturation decreases in the specular direction with the incidence angle, we also observe that the saturation variations around the specular direction become weaker with an increase of the incidence angle.

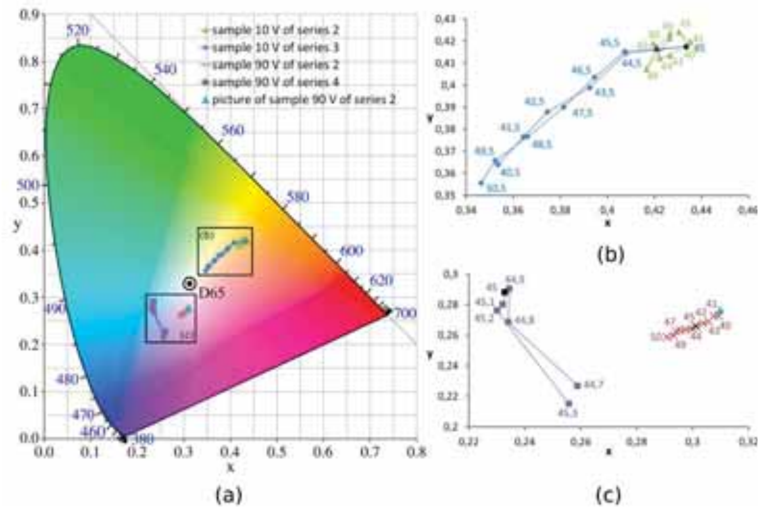

Fig. 6 – (a) Chromatic paths in the CIE chromaticity diagram of the series 2 and 3 samples anodized at 10 V and the serioes 2 and 4 samples anodized at 90 V. The incidence angle is equal to 45°. The central surrounded black dot represents the D65 illuminant. Sub-figures (b) and (c) corresponds to magnifications of the chromatic paths of (b) the samples anodized at 10 V and (c) the samples anodized at 90 V. The values indicated next to the data points on the graphs are the angular positions, in degree, of the detection arm. For the sake of clarity, not all detection arm positions are indicated. The light blue triangle in sub-figures (a) and (c) corresponds to the (x,y) chromaticity coordinates of the 90 V sample of series 2 deduced from a colorimetrically calibrated digital picture of the sample, in the specular direction and for an incidence angle of 45°. The black points in sub-figures (b) and (c) indicate the specular direction.

4. Conclusion

The development of materials with particular visual effects has a wide range of applications in industry. However the characterization of their appearance is challenging, because these effects are linked to sharp variations of the reflectance.

This paper presents first a short review of existing characterization devices. Then colorimetric characterizations of gonio-apparent anodized titanium samples, through a purpose-made gonio-spectrophotometer with high angular resolution are presented. These characterizations constitute a first step for quantifying and ultimately modelling of the chromatic paths that can be obtained with anodized titanium. For a deeper understanding of these observations, a further study is being conducted to link physico-chemical and optical properties of the metal/oxide system.

As titanium exhibits excellent mechanical and physical properties, developing titanium based materials with exciting visual effects is very promising for architects and designers (they already have been demonstrated to be suitable for jewel production [30]). Moreover, as anodized titanium surfaces are very stable, this metal/oxide system is promising for the development of physical standards of gonio-appearence. Existing standard calibration colorcharts allow the rapid and accurate colour characterization of lambertian surfaces. The development of reference colorcharts, possibly using the Ti/TiO_2 system, with a set of well-calibrated gonio-apparent colours is promising for accurately characterizing the visual rendering of gonio-apparent surfaces. It requires further investigations of the structure and optical properties of the oxide layers, complemented by electromagnetic modelling of the interference colours.

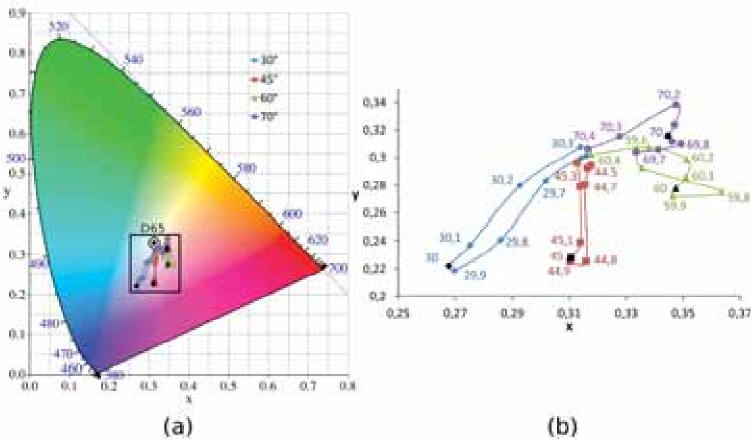

Fig. 7 – Variation of the colour of the 90 V sample of series 1 around the specular direction for various incidence angles: 30°, 45°, 60° and 70°. The blackened points correspond to the specular direction. Sub-figure (b) is a magnification of the surrounded area of sub-figure (a). The values indicated next to the data points on the sub-figure (b) are the angular positions, in degree, of the detection arm. For the sake of clarity, not all detection arm positions are indicated.

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2. COLOUR AND DIGITAL

A Low Power Color Sensor for Illuminant Invariant Skin Detection

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1. Introduction

The recent wide diffusion of smart mobile devices such as phones, tablets and wearables, poses major challenges in the development of more and more advanced sensing technologies, that not only must be energy efficient but also smart and pro-active. To keep the place in the market competition, the mere sensor it is not sufficient; some sort of signal processing must be anticipated as early as possible, integrated in hardware or embedded on an attached microcontroller, providing updated functionalities, combining the collection of raw data with significant features extraction. This trend is thightly coupled with the need for energy efficiency since, for example, in many cases data processing leads to data reduction and therefore to a drop in data transmission, which in most embedded systems is one of the higher contribution to power consumption.

In this work we describe an embedded vision system for color based detection of human skin. The system consists of a low power color sensor whose fundamental units are a RGB pixel sensor and an energy efficient micro-controller, enabling on-board processing. The RGB pixel sensor, recently presented in [1], captures the color signal in auto-exposure mode, converts it into the rg chromaticity space, and delivers the rg coordinates to the micro-controller, which classifies this signal as skin or non-skin [2]. The classification is performed on a skin locus, i.e. on a 2D compact region of the rg space including the skin tones' chromaticities imaged under different Planck's illuminants, such as direct sunlight, daylight, candles, and fluorescent lamps. rg points with chromaticities falling out of the skin locus are classified as non-skin. According to this principle, the skin locus acts as an illuminant invariant filter to select image pixels possibly representing skin.

The innovative architecture of the color sensor allows it to preprocess the acquired data. In fact, the conversion of the acquired RGB signal into rg coordinates is performed directly on the chip with no DC power consumption. Furthermore, the auto-exposure mode guarantees an accuracy on the rg signal higher than the accuracy that can be obtained by processing an RGB signal recorded in non auto-exposure mode.

In this work, we present the application of the color sensor to implement a contactless switch that activates an appliance (e.g. a mobile device, a ticket machine, a kiosk information), by approaching a hand. In this framework, the color sensor works in tandem with a proximity sensor. We present preliminary experiments showing that the color information improves the performance of a switch relying only on proximity data.

The paper outlines as follows. Section 2 introduces the skin detection problem, describes the rg space and the skin locus, and motivates the choice of the rg chromaticities for modeling and detecting human skin. Section 3 illustrates the operating principle of the color pixel and the implementation of the skin classification on the micro-controller. Section 4 reports our experiments. Finally, Section 5 contains our conclusions and future work.

2. Color-based Skin Detection in rg Chromaticity Space

Skin detection is the classification of the pixels of an input image as human skin or not. Skin detection is relevant to many computer vision applications, like face detection, people tracking, hand gesture recognition, content-based image annotation and retrieval [3] [4] [5] [6] [7] [8] [9].

The choice of color as visual descriptor of the skin appearance is justified by many previous works, e.g. [3] [10] [11] [12] [13]. In fact, color is a powerful discriminative feature, robust against geometric transformations, like translation, rescaling, in-plane rotation, and against Gaussian noise addition [14]. Moreover, in several real-life scenarios, skin color is distinctive from the surround and allows a fast classification of the image pixels in skin or non-skin regions [15] [3] [2]. Finally, as reported below, differently from other algorithms, as for instance the recognition of the fingerprints, the color based skin classification method we consider here has a low complexity and it is suitable to be implemented efficiently by means of a low cost electronics with energy saving characteristics. We also notice that the skin detection performed by our sensor does not process sensitive data, as for instance the fingerprints, for which the user approval is needed.

Different color spaces have been introduced to model human skin tones, as RGB [16], YC_bC_r [15], rg [2], HSV [17], CIELab [18], CIELUV [19], TSL [20]. As pointed out in [21], there does not exist an *absolute optimal* color space for skin detection, but the choice of a color space among the others mainly depends on the application at hand. For instance, the RGB space is not suitable for detecting skin under a light with varying intensity. In this case, color spaces separating the intensity of the pixel from its chromaticity, as for instance HSV, CIELUV, CIELab, are more appropriate. A comprehensive review about the color spaces for skin detection is available in [13], [22], [23], [24].

In this work, we model the human skin color in the rg chromaticity space. The chromaticity coordinates (r, g) at a point x of an imaged scene are related to the (R, G, B) coordinates of x as follows:

$$(r, g) = \left(\frac{R}{R+G+B}, \frac{G}{R+G+B}\right)$$

where $R + G + B \neq 0$, and (r, g) = (0, 0) otherwise. Chromaticities range over the interval [0, 1].

We choose to use the rg chromaticity color space among the others for three main reasons: (1) the rg coordinates are robust against changes of illuminant intensity, (2) the skin tones imaged under various illuminants can be represented as a compact

cluster on the rg space, (3) the transform from RGB to rg space is suitable to be implemented on-chip, because the rg computation can be accomplished through analog sum and comparison: these two operations can be efficiently implemented in Silicon at pixel level using few transistors [25].
These issues are discussed in the following Subsections.

2.1. Invariance against variations of the illuminant intensity

In principle, the chromaticity coordinates are invariant against changes of light intensity, caused for instance by shadows or by varying the distance of the light source from the observed scene. Mathematically, changes of light intensity are modeled as a linear transform that maps (R, G, B) to $\alpha(R, G, B)$, where α is a strictly positive real number [26]. Dividing the components R and G by the brightness $R + G + B$ (when this differs from zero) makes the rg coordinates insensitive to such a transformation.

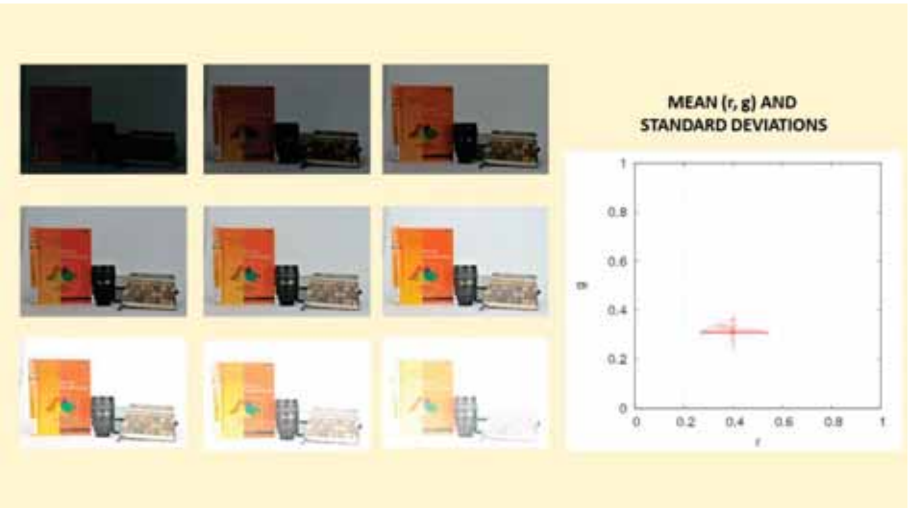

Fig. 1: A same scene acquired under a uniform light with different exposure times: the (r, g) points exhibit a large variability, as shown in the plot on right. The error bars represent the standard deviations on the mean rg values averaged over the image.
The nine pictures on left are available at http://utopia.duth.gr/~dchrisos/pubs/database2.html.

Nevertheless, in practice, the rg coordinates are robust to light intensity changes upon a certain extent. In some scenarios, characterized by very dark and/or very bright illuminants, the RGB signal acquired by a standard camera cannot capture reliably the color information. This adversely affects the computation of the rg coordinates. Let us consider, for example, the pictures in Fig. 1: the nine images on left shows the same scene acquired by a standard camera with nine different shutter speeds. The variation of the shutter speed simulates the variation of the intensity of the scene illuminants: higher (lower, resp.) the speed is, brighter (darker, resp.) the picture is. The plot on the right shows, for each image, the mean value of the rg chromaticities averaged over the number of pixels, and the standard deviations: the

points are quite sparse in the rg plane and the standard deviations are very high, especially for the darkest and brightest images. This means that in these cases, the rg components computed from the RGB signal are quite sensitive to the light intensity and therefore unreliable.
Our sensor overcomes this problem by enabling the auto-exposure control that allows to capture reliable data over a range of 105 dB [1].

2.2. The Skin Locus

The rg space has been proved to be a good space to model and detect human skin regardless of the light intensity [5]. In fact, the rg chromaticities of the human skin acquired under Planck's illuminants form a 2D compact set in the rg plane, called *skin locus* [27]. Planck's illuminants are lights behaving as black body radiators that adsorb and re-emit incandescently radiations in a continuous spectrum. Many common lights, such as daylight, direct sunlight, candle's lights and several fluorescent lamps, are Planckian. Therefore, the points of the skin locus correspond to the chromaticities of the human skin imaged under many common illuminants.
The skin locus S is often described as the rg region delimited by two quadratic polynomials $d(r)$ and $u(r)$, i.e.

$$S = \{(r, g) \in [0,1] \times [0,1]: d(r) \le g \le u(r)\}.$$

The *skin classification* based on the skin locus is performed as follows: if the (r, g) chromaticity of an image pixel falls in to the skin locus, i.e. $d(r) \le g \le u(r)$, then that pixel probably represents skin. According to this principle, the skin locus works as an illuminant invariant filter and provides a binary classification (skin / non-skin) of an input image.

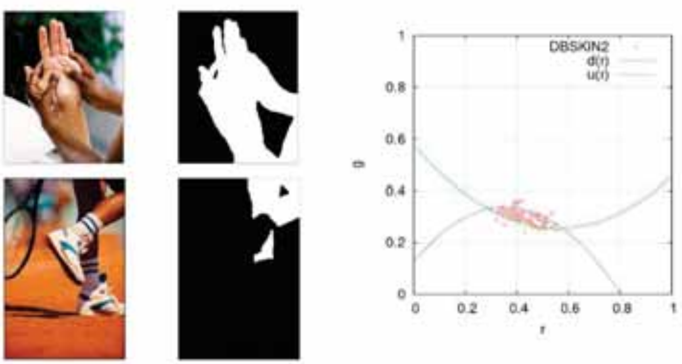

Fig. 2: Some pictures from the public database [28] (on left) and skin locus computed from this dataset (on right). For each color picture of this dataset, the image region occupied by skin is specified by the white pixels of a binary mask. The rg diagram shows also the analytic functions approximating the boundary of the skin locus.

The binary classification provided by the skin locus is robust against geometric distortions, as rescaling, rotations, translations, skew, and thus is appropriate for detecting deformable objects like hands. The main drawback of this classification is due to possible false positives that occur when objects with skin-like chromaticities are displayed in the image. In this case, the skin locus based classification is usually refined by considering statistical and spatial information about the color distribution of skin and non-skin regions [3] [2] [4]. However, in the contactless switch application we discuss here, we focus on the skin locus based classification only.

The *skin locus for a digital camera* can be easily constructed by imaging human skin under different Planck's lights. Since the color responses captured by the camera depend on the spectral sensitivity of the camera, the skin locus also depends on the camera photometric cues. Moreover, the size of the skin locus is determined by the number of the illuminants considered in the acquisition process. Usually, the range of the illuminations is chosen according to the applicative scenarios, e.g. skin detection in outdoor or indoor places.
For a standard RGB camera, the procedure for computing the skin locus consists of the following steps:

1. Acquisition of human skin tones under different illuminants;
2. Data filtering, necessary to remove possible noise from the acquired data. Noise can be due to the presence of pixels captured under too dark or too bright lights or to rg points rarely occurring. The selection of the more reliable data is usually performed by rejecting rg chromaticities with low occurrences in the acquired data.
3. Estimation of the curves approximating the boundary of the skin locus from the data selected at the previous step.

Fig. 2 shows the skin locus computed from a set of real world color pictures captured by a standard camera and displaying human skin under various uncontrolled illumination [28].

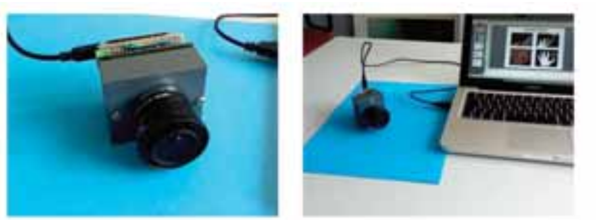

Fig. 3: The prototype of the proposed color sensor.

2.3. Hardware Implementation

The proposed RGB pixel topology is suitable to be integrated into an array of sensors. Precisely, the architecture takes inspiration from the CMOS vision sensor in [25], although the latter refers to image contrast extraction.
Embedding color space transformation into the pixel has several advantages against a standard RGB imager:

1. the output is insensitive to light intensity, because the computation of the rg coordinates is performed over a wide dynamic range; in a conventional

imager, such an invariance would be achieved only by means of a multi-exposure image acquisition;

2. the resulting power consumption is in the order of tens of μW, about two orders of magnitude lower than a commercial sensor.

The main drawback in using the proposed RGB pixel sensor is the larger pixel pitch (about 10μm-15μm), due to the electronics needed to embed the local processing.

3. The Color Sensor

In this work, we use a proof-of-concept prototype built with off-the-shelf components, as shown in Fig. 3. The prototype consists of a RGB color pixel (S9032 from Hamamatsu [29]) interfaced by a micro-controller (MCU) Arduino [30]. A 6 mm optics has been adopted, providing a field of view of 20° for such a sensor size.

3.1. The RGB Pixel

The architecture of the RGB pixel has been recently presented in [1].

Fig. 4 (A) shows the operating principle of the RGB pixel: after being pre-charged to the reset voltage V_{res}, the RGB photodiodes discharge at a slope proportional to the light intensity. The pixel can work in

1. *Standard mode*: the values of R, G, B are sampled at a fixed time T;
2. *Auto-exposure mode*: a threshold TH on the maximum voltage V_{res} is fixed; during the exposure time, the RGB pixel computes the intensity $S(t) = R(t) + G(t) + B(t)$ and samples the R, G, B values when $S(t)$ reaches the value TH. Therefore, the value $t = T_D$ such that $S(t) = TH$ is specific for each acquired signal and

$$r = \frac{R(T_D)}{TH}, g = \frac{G(T_D)}{TH}.$$

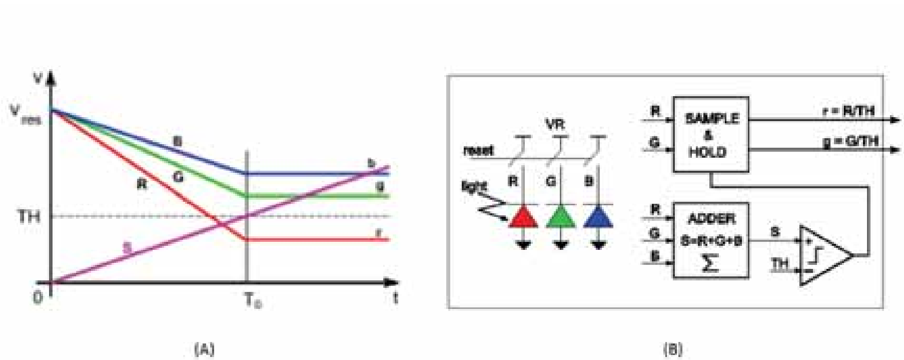

Fig. 4: (A) signal sampling; (B) block diagram of the color pixel.

Fig. 4 (B) shows the block diagram of the sensor. The color photodiodes provide the RGB voltage signals to an analog ADDER, which computes $S(t)$ on-the-fly, during the exposure time. $S(t)$ is then compared with the threshold TH by means of a voltage comparator, triggering the SAMPLE&HOLD block which samples the

signals R, G. The output (r,g) is delivered to the MCU for the AD conversion and processing.
As already pointed out in the previous Section, the data acquisition in auto-exposure mode provides a more accurate signal than that obtained by exploiting the standard mode. The rg chromaticities are in this case captured with a high dynamic range of up to 105 dB [1]. Fig. 5 reports the rg points coming from a gray surface captured by the RGB pixel under a light with varying intensity (about 40 dB): the data acquired in standard mode is sparser than that acquired with auto-exposure mode.
A comparison between the main characteristics of the proposed RGB pixel sensor and a standard one is reported in Tab. 1.

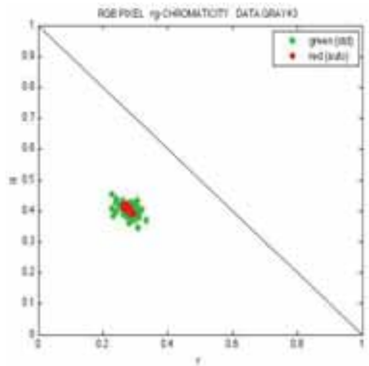

Fig. 5: Sensor response in auto-exposure and standard operating modes respectively. In this test, the gray pattern of the color-checker has been used, changing the light intensity of about 40dB.

Parameters	This RGB pixel	Standard RGB pixel
Exposure control	Pixel-level auto-exposure	Global exposure control
Dynamic range	105 dB	~60dB
Output	On-pixel color space conversion	Standard RGB output
FOM	~600pW/pixel •frame	7nW/pixel•frame

Tab. 1: A comparison between some parameters characterizing the proposed RGB pixel sensor (“This RGB pixel”) and a standard imager. In our case, FOM (Figure Of Merit) is the power consumed by one pixel to execute the required operation within one frame. Although the FOM in our approach is about 10 times better than that one of a standard imager, the effective improvement is even better. In fact, while 7nW/pixel•frame refers to a pixel delivering RGB signal with 60dB, in our approach 600pW/pixel•frame also includes the RGB space transformation which should be otherwise accomplished by an external processor with much larger power consumption.

3.2. The micro-controller

The RGB pixel is interfaced with a low-power MCU responsible of the acquisition of the output (r,g) coordinates, of their classification as skin or not skin and of the communication with an external host device (e.g. a PC). In this first implementation, we used the Arduino Nano board, exploiting the available ATMega328 as MCU, the integrated serial to USB interface and pin connectors [30].

The interface between the sensor and the microcontroller is composed by two control signals (RESET and SH) and the two analogue (r, g) signals to acquire. The RESET signal, set by the MCU, resets the sensor and triggers the pre-charge of the photodiodes necessary for each acquisition. The SH signal, set by the sensor in auto-exposure mode, notifies the end of the sensor sampling and the availability of the r and g signals for acquisition, which are then acquired using two Analogue-to-Digital converters of the MCU. In addition to this auto-exposure functionality, the system can use a fixed exposure time by ignoring the SH signal and sampling the (r, g) signals after a fixed amount of time.
Once the (r, g) signals are acquired, the MCU checks if they represent skin by evaluation the two equations $d(r)$ and $u(r)$. The coefficients of the equations are obtained during an offline learning phase (i.e. the skin locus computation) and are stored in the MCU. The computation of the two equations requires 9 multiplications and 4 additions, plus 2 compare operations, which can be easily handled by the MCU within the acquisition period guaranteeing real-time execution.
Both the sampled data and the classification results are sent to the host PC via the serial interface. On the PC side, a *Processing* application (https://processing.org/) collects the data, plots it in real time for user feedback and stores it for further offline analysis.

4. Experiments

We present the usage of the color sensor as a contactless switch that activates an appliance by a hand gesture. In our scenario, the gesture is just the waving of the hand in front of the sensor. In this framework, the sensor works in tandem with a proximity sensor. Precisely, when the color sensor detects skin, it activates the proximity sensor that checks if something is located in front of the sensor at a distance of about 5 - 10 cm. If so, the switch activates the appliance. If the color detected by our sensor does not change within 3 seconds, then the sensor switches off the device, because the detected skin does not correspond to a gesture (that is supposed to be a rapid movement of the hand with a consequent fast change of color and distance).

Fig. 6 (B) reports the skin locus of our sensor, computed according to the procedure described in Section 2.2. Precisely, we considered 15 illuminants with correlated color temperatures between 2700K and 7000K, including warm, natural and cold lights. The used illuminants are commonly present in indoor environments as office and home, and in outdoor cloudy places, not illuminated by the direct sunlight. We did not considered direct sunlight in the skin locus construction, because generally devices like ticket machines or kiosk information are not located under direct sunlight, that makes difficult to read the information displayed on their monitors.
For each illuminant, we captured the skin tones of 10 volunteers coming from different countries, in order to collect the skin tones of different ethnic groups. The total number of skin chromaticities we collected in this experiment is 150. People have been asked to put the palm of a hand in front of the color sensor at a distance of about 5-10 cm and to hold the hand as much as possible fixed in that position to

reduce possible noise. We computed the histogram of the acquired data, by partitioning the rg space in 100×100 cells. We normalized this histogram so that it sums up to 1.0 and we removed the rg points occurring less than 0.034 % in the acquired dataset: these points correspond to bins where the histogram value is smaller than 0.00034 and they often represent local skin imperfections or noise due to an unstable position of the hand in front of the sensor. The histogram and the skin locus computed from the filtered data are shown in Fig. 6 (A) and (B) respectively. The boundary of the skin locus region is approximated by the polynomials:

$$u(r) = -2.668\, r^2 + 2.336\, r - 0.152$$
$$d(r) = 0.027\, r^2 - 0.242\, r + 0.372.$$

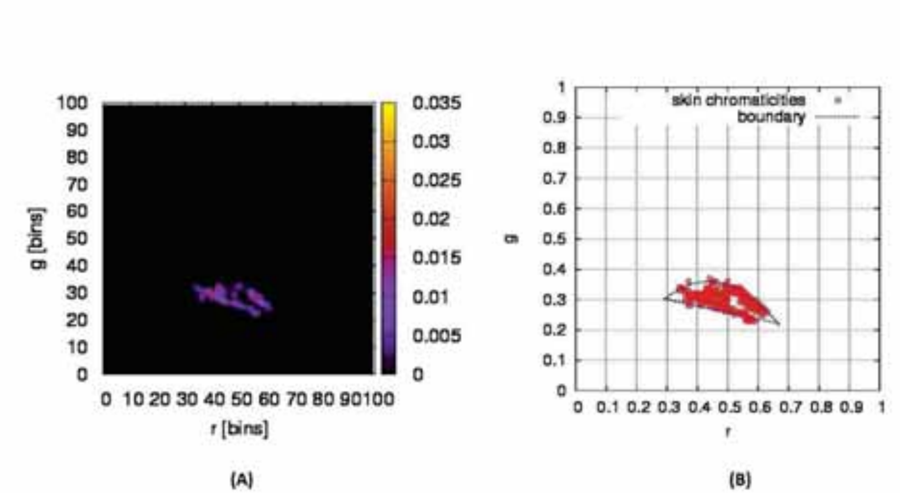

Fig. 6: (A) histogram of the rg coordinates sampled in the skin locus acquisition phase; (B) our skin locus.

The proposed sensor is currently under testing. Here we report some preliminary experiments to test the skin classification performance of our sensor and thus of the proposed contactless switch. We evaluated the performance by acquiring skin tones and non-skin tones and computing the percentages of skin tones and non-skin tones correctly labeled as SKIN and NON-SKIN respectively, and the percentage of false positives, i.e. the percentage of non-skin objects wrongly classified as SKIN.
These experiments were organized in two groups.

In the experiments of the first group we illuminated a MacBeth color checker and the palm of a hand with 8 different lights similar to those used for the skin locus computation. The first two colors displayed on the color checker represent dark and light colors of the human skin. These two colors and the hand skin have been always correctly classified as skin by our sensor. The 85.23% of the other 176 rg points (i.e. the chromaticities of the non-skin 22 colors of the color checker imaged under the 8 lights) have been correctly labeled as non-skin, while we reported 14.77 % of false positives. A proximity sensor would activate the device connected to it in the 100%

of the cases. Therefore, the improvement provided by using color is remarkably significant (85.23 %).

In the second set of experiments, we measured the performance of our system by acquiring the colors of real-world objects present in a scene. We positioned our sensor in 15 different environments (including indoor and outdoor places) with different natural or artificial illuminations perceived to be similar to those used for the skin locus computation. In each place, we asked a person to put in front of the sensor his/her hand and an object randomly chosen in that ambient. We collected 15 measures of rg points corresponding to human skin and 15 measures of rg points corresponding to non-skin objects. The skin has been correctly detected in 14 cases, while in one case we reported a wrong label. About the 73.34% of the non-skin objects has been correctly classified as non-skin, while the percentage of false positives is 26.67%. In two cases, people showed objects with chromaticity very similar to that of the human skin (see for instance the doll in Fig. 7), thus very difficult to classify. Nevertheless, as before, the usage of the color information remarkably improves the performance of a proximity based switch.

The results obtained in these experiments are summarized in Tab. 2.
The 23 human skin tones acquired in these experiments have been classified as SKIN in 22 cases, with a percentage of correct classification equal to 95.65%. If we consider also the two skin colors of the MacBeth chart as human skin, the percentage of correct classification is 97.37%.

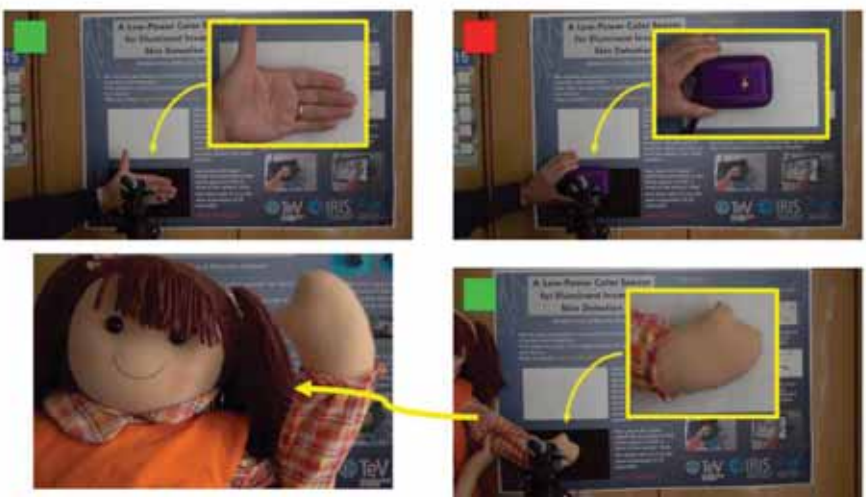

Fig. 7: some classification results: in these experiments we ask a person to put her/his hand and another object in front of the sensor. The hand and the object are shown in the yellow boxes. In the first row, the hand and the purple object have been correctly classified as skin and non-skin. In the second row, the hand of a doll has been put in front of the sensor and erroneously classified as human skin. The red and green boxes on the top left corner indicate respectively the labels SKIN and NON SKIN associated to the processed signal.

5. Conclusions

In this paper, we presented a novel low power color sensor tailored to illuminant invariant skin detection and we discussed its usage as a contactless switch where the proposed sensor works in tandem with a proximity sensor. Preliminary experiments showed that the use of color improves the performance of a contactless switch based on a proximity sensor. In fact, our sensor provides high accuracy for the skin detection under many common illuminants and remarkably reduces the number of appliance activations.

Future work will include new experiments to test the performance of the sensor and the integration in the classification algorithm of additional features for improving the skin detection and for further decreasing the percentage of false alarms.

Experiments	Percentage of Skin Tones Correctly Classified	Percentage of Non-Skin Tones Correctly Classified	Percentage of False Positives (Non-Skin Tones Classified as Skin)
Set 1	100 %	85.23 %	14.77 %
Set 2	93.34 %	73.34 %	26.67 %

Tab. 2: Experimental results.

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BID (Bruteforce Isoluminants Decrease) a RGB-to-gray conversion technique for automatic photogrammetry

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1. Introduction

The fast technical advances in the field of automated photo-modelling over the last few years led to availability of many freeware, on-line, and commercial software (e.g. Autodesk ReCap, ARC3D, VisualSFM, Acute 3D and Agisoft PhotoScan). This software can perform a semi-automatic 3D reconstruction from a collection of images, in a context in which different people may have taken these images at different times and with different cameras. Common images and points have to be recognised and merged to produce a model, by means of matching algorithms that allow identifying accurate correspondences. These correspondences are then used in SFM algorithms to estimate the precise camera pose, which are finally used as input into multi-view-stereo (MVS) methods that produce dense 3D models with a comparable accuracy to laser scanners [1].
In the automatic reconstruction of 3D objects and environments from two or more photographic sets, few solutions are able to take advantage of color information. Almost all these reconstruction methods are conceptually designed to work on grayscale images in the sense that, sooner or later in the processing, for a given spatial location, the algorithm will only consider a single intensity value instead of the RGB triple. Often, this single numerical value is the result of a simple aggregation of color values. That is also our case where algorithms both for sparse and dense phase works using only the luminance channel.
Color-to-gray conversion is factually a *dimensionality reduction* problem. This process should not be underestimated, since there are many different properties that need to be preserved. Isoluminant color changes are usually not preserved with commonly used color to gray conversions. In any case, we can state that the 3D to 1D dimension reduction leads to information loss and that the appearance of this loss is related to the method.
Many conversion methods have been proposed in recent years; these methods mainly focus on perceptual accuracy in terms of the fidelity of the converted image when reproduced from color to grayscale tones. These kinds of approaches are not designed to fulfill the needs of visual stereo matching and image matching algorithms, where local contrast preservation is crucial in the process of matching by local operators. This is one the main reason why in Lowe’s “Scale-invariant feature transform” (SIFT) operator, the candidate key-points with low contrast are rejected in order to decrease the number of ambiguous points in the matching process [2].
Enhancement of the images forming the convergent photogrammetric network through pre-processing could be an important step for subsequent feature extraction and image matching and finally for dense stereo matching. Research has found that a filter is warranted to provide detail in shadowed areas and saturated areas simultaneously, and thus to allow a greater number of interest points to be detected.

To face these issues, we evaluated many different state-of-the-art algorithms for color-to-gray conversion with the goal to understand what could improve the quality and the accuracy of results applying a gray scale conversion as a pre-processing step in the context of image matching and multi-view stereo matching.
In an exploratory phase, we attempted to adapt the most promising algorithm (from a theoretical viewpoint) in order to create an ad-hoc algorithm hopefully able to optimize the conversion process by simultaneously evaluating the whole set of images. Using this new solution, we implemented two different procedures of image filtering with two different but complementary purposes [3], corresponding to the two phases of construction of sparse and dense cloud of points:

1. Sparse phase: higher correct matching in the less time possible, that is: track blobs along the largest number of images possible;
2. Dense phase: largest number of points possible less noised as possible.

In this paper, we present the *BID* (Bruteforce Isoluminants Decrease) color-to-gray conversion technique that combines the idea of evaluating a whole set of images instead of a single one in order to preserve tonal coherence during the matching phase with a specifically developed measurement criterion used to evaluate the decolorization quality. We move in the well-delineated context in which authors [4] demonstrated that a preprocessing approach for RAW imagery (i.e. images containing unprocessed pixels saved as it was captured by the sensor since it contains the values just after the analog-to-digital conversion, without any of the camera processing enhancements applied) can yield significant photogrammetric accuracy improvements over those obtained with JPEG.
In our consideration, only the basic in-camera processing was retained: black point subtraction; bad pixel removal; dark frame, bias subtraction & flat-field correction; green channel equilibrium correction; Bayer interpolation. To avoid as much as possible modify the RAW pixel values to some extent we did not allow on-camera: denoising; color scaling; image sharpening; color space conversion; Gamma correction; format conversion. These pre-processing steps were done using an automated procedure described in [3]. This procedure consists in a calibrated and customized version of the on-camera processing, which consistently fit our aims. The result of this pre-processing is a rendered image in the sRGB color space, since this is the typical automatic photogrammetry software when you are in production.
Background papers of our study are [5] and [6]. The first paper is focused on color-to-grey conversion to improve image matching using SIFT and SIFT-like operators. The second one aims to develop a new method to improve stereo-matching and multi-stereo matching results. Our development confirmed the main results illustrated in the above papers (e.g. efficiency of color-to-grey methods for SIFT feature-matching) and shows the efficiency of the BID technique to improve multi-view stereo-matching.

2. Color-to-gray conversion problem and existing techniques

Many color-to-gray conversion methods have been proposed in recent years, but they mainly focus on quality of grayscale printer reproduction and other human-related tasks. These conversions can be done in Color Space (linear or nonlinear) or in Image Space converting pixels (RGB) using colors in the image and assigning different gray for different color.

Between the conversions in Color Space the CIE Y method is a widely used conversion that is based on the CIE 1931 XYZ color space. It takes the XYZ representation of the image and uses Y as the gray value. For images having isoluminant regions, the luminance channel will fail to represent structures or features in the color image.

Image Space color-to-grey conversions are image-independent local functions of every color, e.g., for every pixel of the color image a gray value is computed using a function whose only parameters are the values of the corresponding color pixel.

Following [6] Image Space conversions can be subdivided into three subfamilies:

- trivial methods
- direct methods
- chrominance direct methods.

Trivial methods are the most basic and simple ones. They do not take into account the power distribution of the color channels; for example, only the mean of the RGB channels is taken. They lose a lot of image information because for every pixel they discard two of the three color values, or discard one value averaging the remaining ones, not taking into account any color properties. Despite the loss of information these color to grayscale conversions are commonly used for their simplicity.

Typical example of trivial method is the *RGB Channel Filter* that selects a channel between *R*, *G* or *B* and uses this channel as the grayscale value. The green filter gives the best results, due to the sensors Bayer pattern configurations and because the green channel is typically very similar to the luminance channel, and the blue filter gives the worst results in terms of lightness resemblance. For images having many colors in the green field we have a lot of information missed.

Direct methods are standard methods where the conversion is a linear function of the pixel's color values. The simplest solution is obviously the *Naive Mean* that takes the mean of the color channels; but the true advantage of direct methods compared to the trivial ones is that, because they take information from every channel, it's possible to have different weights for different colors means. This allows taking into account factors such as the relative spectral distribution of the color channels and the human perception. Many of the most used grayscale conversion are based on a method of this family.

The most popular of direct methods is the MATLAB RGBtoGrey that converts from RGB to grayscale, using the NTSC CCIR 601 luma weights, with the formula

$$Y = 0.2989R + 0.5870G + 0.1140B$$

Another solution embedded inside Adobe Photoshop use as specific weights to channels R, G, and B: 0.4, 0.4, 0.2.

RGB channel filters are not at all affected by gamma compression problems, since they do not manipulate color values but only choose one of them; this is one of reason of its attractiveness also in our field.

Chrominance direct methods are based on more advanced color spaces and are able to mitigate the problem related to isoluminant colors. These conversions are still local functions of the image pixels, but they assign different grayscale values to

‘isoluminant’ colors. To achieve this result, the luminance information is slightly altered using the chrominance information. In order to increase or decrease the ‘correct’ luminance to differentiate isoluminant colors, these methods exploit a result from studies on human color perception as the Helmholtz-Kohlrausch (H-K) effect [7]. The H-K effect states that the perceived lightness of a stimulus changes as a function of the chroma. This phenomenon is predicted by a chromatic lightness term that corrects the luminance based on the color’s chromatic component and on starting color space.
In general, chrominance direct methods can be performed either locally or globally.
Local chrominance direct methods [8] make pixels in the color image not processed in the same way and usually rely on the local chrominance edges for enhancement. Smith et al. [9], e.g., employ a local sharpening step after obtaining the grayscale image by global mapping: an adaptively weighted multiscale unsharp masking enhances chrominance edges. In our field the use of local methods presents many problems: could appear local changes, contradictions, and they have high computational costs. Mainly these techniques might distort the appearance of constant color regions (e.g. same color may output different gray value) and, using color contrast map to enhance gray image, may produce haloing artifacts, as discussed in [10]. These are consistent problems in our case because SIFT blob features will be altered in differently in different images with different point of view and exposure, preventing the correct matching.
Global methods strive to produce one mapping function for the whole image. In this way you will have same luminance for the same RGB triplets and high-speed conversion. Mostly, color order is strictly satisfied, also it might be ambiguous for the human perception. E.g. Grundland and Dodgson [11] proposed a fast linear mapping algorithm that adds a fixed amount of chrominance to the lightness, where the original lightness and color order can be better preserved by restraining the added chrominance. Benedetti et al. [6] demonstrated the best results using this method, but our studies demonstrated that it fail when you have different luminance for the same chrominance (i.e. different exposure of images).

3. Color-to-gray tested techniques

For our context we analyzed several algorithms to cover a wide range of approaches. Concerning Image Space conversions, we chose the *Green-to-Grey* as trivial method and the MATLAB RGB2Gray as direct method because of its relationship with human vision and its popularity in the Computer Vision community.
Between direct methods we tested also Adobe Photoshop conversion using predefined settings. Adobe Photoshop devised also custom non-linear projections, but these require users to set image-dependent parameters by trial and error [12]. For this reason were left out of our tests.
Between Chrominance direct methods, we discarded all methods tested accurately without success in [6] and also the methods discarded by this study with consistent motivations. E.g. *Gooch Color2Gray* [13] not was implemented because other experiences demonstrate that, although its gradient-preserving nature could improve features discriminability, in practice it does not improve the quality of the results be-

cause of its inherent problems with the input parameter selection and its inconsistent spatial locality. We implemented the local methods Smith et al. [9] technique but we abandoned them soon due the problems in our MVS software (nFrames SURE) [14] where its adaptively-weighted multi-scale unsharp mask generate large problems (no models produced in the ground dataset): it's well known that the unsharp masking filter enhances (modify) the fine details of the image and colors are mapped inconsistently between different parts of the images depending on the surrounding neighborhoods. While the algorithm can use spatial information to determine the mapping, the same color should be mapped to the same grayscale value for every pixel in the image. Between Chrominance direct methods we implemented Grundland and Dodgson [11] and two techniques of the same authors: *Contrast Preserving Decolorization* [15] and *Real-time Contrast Preserving Decolorization* [16]. Both based on the same theoretical framework and algorithm, they differ only for simplification technique introduced with the latter.
We found that in our case the second solution is more suitable for two reasons:

a. a much shorter and constant (independent from resolution) processing time (less than one second);
b. *Contrast Preserving Decolorization*, to be processed in real time, implements a simplified version of the original equation. This version has the beneficial drawback to convert the patches appearing in different images univocally.

Preliminary tests with both the methods prove the efficiency of the second one.
A detailed description of the chrominance direct methods tested follows.

Grundland and Dodgson

Grundland and Dodgson [11] performed a global grayscale conversion by expressing grayscale as a continuous, image-dependent, piecewise linear mapping of the primary RGB colors and their saturation. Their algorithm, called *Decolorize*, works in the YPQ color opponent space and aim to contrast enhance. The color differences in this color space are projected onto the two *predominant* chromatic contrast axes and are then added to the luminance image. Unlike principal component analysis, which optimizes the variability of observations, predominant component analysis optimizes the differences between observations. The predominant chromatic axis aims to capture, with a single chromatic coordinate, the color contrast information that is lost in the luminance channel. The luminance channel *Y* is obtained with the NTSC CCIR 601 luma weights. Grundland Decolorize is very sensitive to the issue of gamma compression with some risks of decrease of the quality of the results mainly in light areas or dark areas where many features will be lost because the saturation balancing interacts incorrectly with the outlier detection.

Real-time Contrast Preserving Decolorization

The human visual system does not univocally perceive chrominance and lightness, while their relationship to the adjacent context plays a vital role and that the order of different colors also cannot be defined uniquely by people, Lu et al. [13] relax the color order constraint and present a new method seeking better preservation of color contrast and significant enhancement of visual distinctiveness for edges. For color pairs without a clear order in brightness, authors propose a bimodal distribution, i.e., mixture of two Gaussians, to automatically find suitable orders with respect to the visual context in optimization. This strategy enables automatically finding suitable gray scales and preserves significant color change. Practically they use a global mapping scheme where all color pixels in the input are converted to grayscale using the same mapping function (a finite multivariate polynomial function). Therefore, two pixels with the same color will have the same gray scale. The technique is today implemented in OpenCV 3.0. In order to achieve real-time performance, authors further devise a discrete searching optimization which takes advantage of a linear parametric grayscale model as well as a sampling based P-shrinking process [16]. Specifically, they approximate their previous optimization-based method and achieve real-time performance by confining the polynomial color model into a constrained, discrete linear color model. To further speedup the decolorization process, they down-sample the high-resolution input to a small scale 64 × 64. This is valid due to the inherent color redundancy of natural images. Extensive experiments show that the proposed P-shrinking scheme can achieve real-time performance for high-resolution images, without obvious quality degradation. Also if the approximated solution in confined search space might produce unsatisfactory results in special cases this last solution is suitable for our case solving the problem using fixed strategies not linked with perception but with a simple clear order in brightness, also if the above-mentioned methods do not consider the preservation of brightness of the input color image. Main drawback is that in two different images same color could be converted in different grays.

4. The new BID (Bruteforce Isoluminants Decrease) technique

Testing phase of existing algorithm allowed the development of a new conversion technique aiming to transform the image set by preserving the consistency between the images that are to be matched, i.e. able to fulfill the following matching requirements:

- *Feature Discriminability*: the method should preserve the image features discriminability to be matched as much as possible;
- *Chrominance Awareness*: the method should distinguish between isoluminant colors;
- *Global Mapping*: while the algorithm can use spatial information to determine the mapping, the same color should be mapped to the same grayscale value for every pixel in the image;
- *Color Consistency*: besides Global Mapping, the same color should also be mapped to the same grayscale value in every image of the set to be matched;
- *Grayscale Preservation*: if a pixel in the color image is already achromatic it should maintain the same gray level in the grayscale image;
- *Unsupervised algorithm*: it should not need user tuning to work properly.

Basically four considerations are at the origin of our development:

- in combining the channels of a multi-band image with the help of a pixelwise weighted sum usually the weights are given by some standard values or chosen heuristically. This does not take into account neither the statistical nature of the image source nor the intended further processing of the scalar image;
- often an image does not contain the full tonal range, but a subset of tones relatively small, and in the original version and the converted version;

- almost all the previous methods pay more attention to maximize local difference for decolorization but ignore global color distribution, and quantitative evaluation used in these methods only consider neighboring pixel/region pairs;
- in the image matching and multi-stereo existing color-to-gray conversion algorithms works considering the images individually. In this way could be assigned different values of gray the same color in different images.

The new method take from one side the idea of the Benedetti et al. [6] method *Multi-Image Decolorize* of evaluation of the whole set of images in order to match them simultaneously; from the other side develop a framework were are specified the statistical properties of the input data with the help of a representative collection of image patches provided by the same images of which we realize the conversion.

Differently from *Multi-Image Decolorize* that is an adaptation of [11], our conversion is a generalization of the MATLAB RGB2Gray algorithm, which simultaneously takes in input the whole set of images that need to be matched and use unused tones in the image converted to better represent the original and leans to the global distribution of colors.

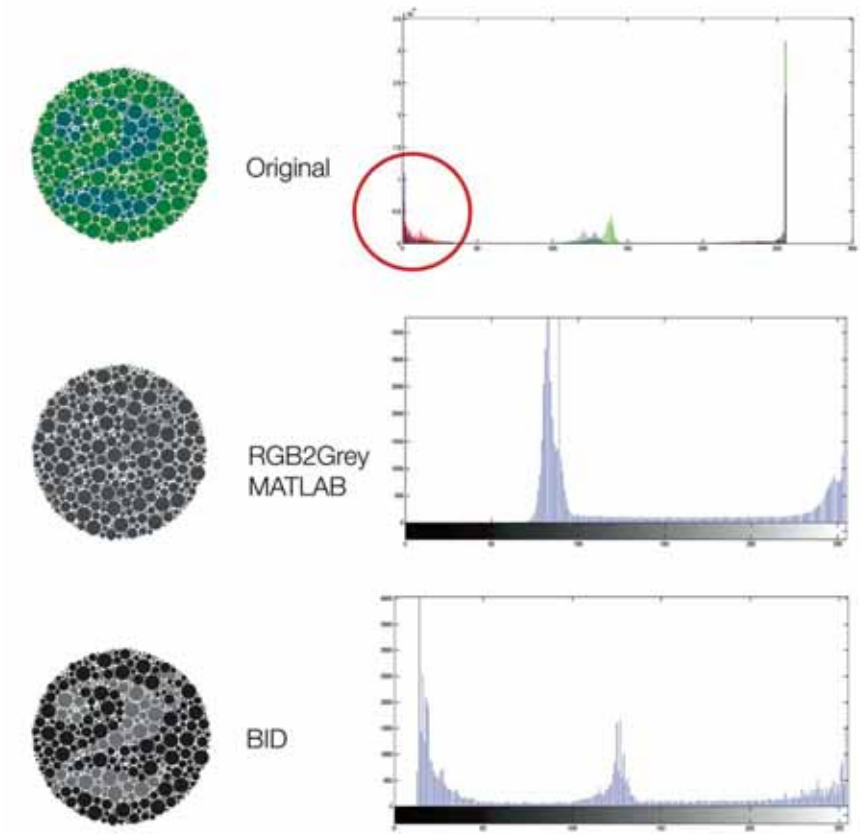

Fig. 1 – Grayscale conversion of an image with isoluminant colors. Image and its histogram (top to bottom): a. original; converted using the MATLAB RGB2Gray technique; converted using the BID technique.

Similar to [17] *BID* employ the typical RGB2Gray conversion model with 66 sets of weights (ωr, ωg, ωb). However, significant critical difference lies in the measurement criterion used to evaluate the decolorization quality. In brief, Song et al. employs the bilateral filtering with high computational complexity; on the contrary, BID is based on the newly defined dominant color hypothesis. *BID* has no claim to realistically converted images from color to greyscale; but to preserve as much as possible the amount of information conveyed. *BID* has its foundation in the statistics of extreme-value distributions of the considered images and presents a more flexible strategy, adapting dynamically channel weights depending on specific input images, in order to find the most appropriate weights for a given color image.
The algorithm behind *BID* tries to maximize the number of peaks obtained in the image converted and to distribute as evenly as possible the amount of tones present in the converted image by evaluating the goodness of fit of the distribution with respect to a rectangular distribution.

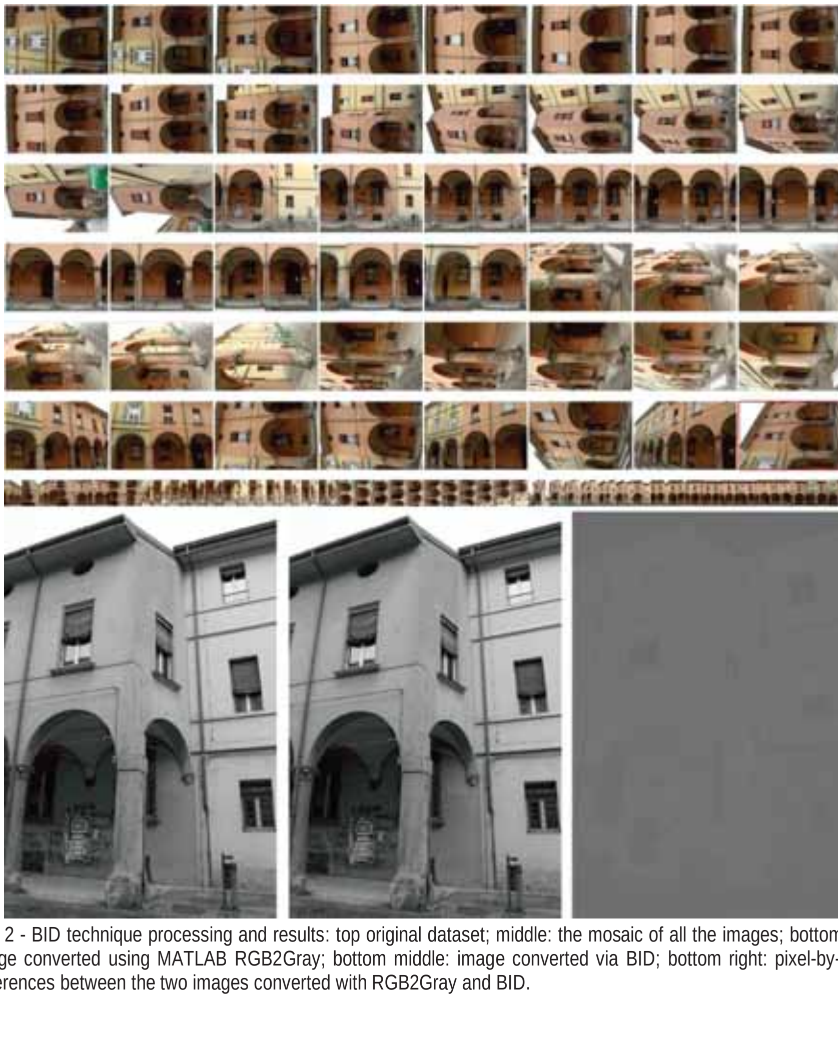

Fig. 2 - BID technique processing and results: top original dataset; middle: the mosaic of all the images; bottom left: image converted using MATLAB RGB2Gray; bottom middle: image converted via BID; bottom right: pixel-by-pixel differences between the two images converted with RGB2Gray and BID.

To calculate the best rectangular fitting we assumed a 0 slope regression line. If the general equation of the regression line is:

$$\beta = \bar{y} - m\bar{x}$$

β is equivalent to the average of the histogram points.
After calculating the average, the minimum error within all the calculated combinations of channel mixing is sought. The error is calculated as least squares error:

$$S = \sum_{i=1}^{n} (y_i - \beta)^2$$

where y_i are the actual points, while β is the best linear fitting of the histogram. *BID* cyclically varies the amount of red, green and blue and for each variation calculates the distribution of the resulting grayscale image and assesses the fitting quality with respect to a rectangular distribution. Finally *BID* chooses the mixing that maximizes the number of tones obtained in the converted image. Similarly to [17], *BID* uses a measurement criterion to evaluate the decolorization quality, i.e. the newly defined dominant color hypothesis.
We try to clarify *BID* behavior with the example in fig. 1. Converting this image with trivial or direct methods, we would get an image similar to the one in the center of the same figure where blue and green are isoluminant and are converted using the same shade of gray. The result of the conversion is a total loss of significant original information. Representing the distribution of tones of the original image and comparing it with the distribution of the converted image we would notice that one of the three peaks of the distribution of the original image is not present in the converted version.
Main disadvantage of *BID* is the high computational preprocessing cost that we alleviate using sampled copies of our dataset at 25%. As said this is valid due to the inherent color redundancy of natural images. In this way the preprocessing time is just some minutes, in any case a little time compared to those of the entire pipeline.

5. Experimental setup and evaluation results

The main approach used to evaluate the correctness of different color to grayscale conversion algorithms is a perceptual evaluation, such as that in [18]. To fit our needs we used, conversely, an approach that is tailored to measure the results of the subsequent image processing algorithms, by evaluating the *effectiveness* of different grayscale conversions with respect to the image-based reconstruction problem in two contexts: SIFT matching [19] and Semiglobal Matching [20].
The following outcomes were analyzed:
- *pairwise matching efficiency*: using a set of images (Fig. 3) featuring illumination differences, textureless surfaces, possible loss of information in the color-to-grey conversion and elements with strong 3D features, we tested pairwise matching efficiency of the operators with respect to three camera movements: (i) parallel with limited baseline (00-01); (ii) rotation of 90° (00-03); (iii) tilt of more than 30° (01-02). The number of correct inlier matches (after the RANSAC phase) is normalized with all putative correspondences (Tab. 1):

$$efficiency = \frac{\#\ inliers}{\#\ putative\ corrispondances}$$

Fig. 2 - Images used to test pairwise matching efficiency

	PARALLEL 00 - 01	ROTATE 90° 00 - 03	TILT 45° 01 - 02
GREENTOGREY	0,992	0,786	0,640
RGBTOGREY	0,980	0,690	0,329
ADOBE PS BN	0,992	0,821	0,630
GRUNDLAND	0,992	0,863	0,626
LU REALTIME	0,992	0,827	0,618
BID	0,993	0,825	0,676

Tab. 1 – Efficiency of each operator.

- *number of oriented cameras*
- *root mean square error of the bundle adjustment*: it expresses the re-projection error of all computed 3D points.
- *visibility of 3D points in more than 3 images*
- *number of point in the dense reconstruction using an unique camera orientation for all the datasets.*

For the evaluation of last four outcomes, two different image networks were used with different imaging configurations, textureless areas and repeated pattern/features. The datasets tried to verify the efficiency of the implemented pre-processing pipeline and evaluate its performances. The first dataset (35 images) pertains two spans of a three floors building (6 x 11 m) characterized by arches, pillars/columns, cross vault and plastered wall. Camera was moving along the porticoes, with some closer shots of the columns (Fig. 2).
The images were acquired - in all three datasets - using a Nikon D3100 with a 18 mm nominal focal length. The two datasets represent an urban test framework and summarizes a typical historical urban scenario. Different image scales, number of images, camera network, object texture and size, characterize them.
These datasets allow verifying the efficiency of different techniques in different situations (scale variation, camera rotation, affine transformations, etc.). The datasets contain, besides convergent imaging configurations and some orthogonal camera rolls, a variety of situations typical of failure cases, i.e. 3D scenes (non-coplanar) with homogeneous regions, distinctive edge boundaries (e.g. buildings, windows/doors, cornices, arcades), repeated patterns (recurrent architectural elements), textureless surfaces and illumination changes.


Fig. 3 - The porticoes dataset


Fig. 4 - The Palazzo Albergati dataset

With respect to other evaluations where synthetic datasets, indoor scenarios, low resolution images, flat objects or simple 2-view matching procedures are used and tested, our datasets are more varied and our aim is the final scene's 3D reconstruction. For every conversion method, and also for the *BID*, the datasets are relatively oriented using Visual SFM [21] and a customized implementation of SIFT point interest detection, description and matching [19], trying to extract a uniform number of keypoints and tie points. Then, a dense point cloud is extracted with a unique tool (nFrames SURE) by using (fixing) the same camera parameters for all methods.
Results show how algorithms are differently affecting the BA procedure as well as the dense matching results (Table 2, 3).
It can be generally noticed for the *BID* a larger number of oriented images, better reprojection errors and denser point clouds, proving its efficiency a pre-processing technique for automatic photogrammetry.

	ADOBE PS BN	Lu Real-time	Grundland	Matlab RGB2grey	BID	Green to grey
Oriented images	33	30	16	33	35	35
PBA quality	0.424	0.366	0.379	0.353	0.581	0.548
Points from more than 3 cameras	3763	3439	524	3874	4872	4759
Dense SURE BA Greentogrey	1444269	1522044	1375971	1184432	1964397	1703607
Point on image _DSC6305	49670	47901	51989	49744	49118	47842
Inlier matches 05-06	533	584	459	588	768	795

Tab. 2 – Dataset Portico 35 – results

	ADOBE PS BN	Lu Real-time	Grundland	Matlab RGB2grey	BID	Green to grey
Oriented images	39	39	39	39	39	38
PBA quality	0.474	0.055	0.048	0.137	0.057	0.052
Points from more than 3 cameras	28885	32704	32158	27418	29545	37069
Dense SURE BA Realtime	27965855	27553306	27710452	27915526	27944181	27821933
Point on image _DSC3201	126634	123279	131131	147514	134504	123891
Inlier matches 01_02	7227	7435	7830	8049	7989	7437

Tab. 3 – Dataset Albergati – results

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The Academy Color Enconding System (ACES) in a video production and post-production colour pipeline

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1. Introduction

Colour management for video-based projects involves transferring large quantities of data —currently 1–3 TB (terabytes) per shooting day, or 1–6 TB per finished full-feature Digital Cinema Master— around different locations and facilities, during a timespan of several months, and having them processed by highly heterogeneous IT infrastructures, each with its peculiar viewing environment at the end (displays, TVs, monitors, projectors). Add to this the different imaging characteristics of camera sensors and purely artificial imagery / computer graphics (CG).

To cope with such a diverse ecosystem, the Academy of Motion Picture Arts and Sciences (AMPAS), as it did many times in the past (from the silent-film era up to current immersive-sound, HFR and HDR breakthroughs), gathered an international group of scientists, cinematographers, developers, colourists and engineers —which the author is among— to came up with a framework called the *Academy Color Encoding System* (*ACES*, [1]) encompassing colorimetry, advanced mathematics ([2]), metadata and computer-science security to streamline an easier, more interoperable and durable process which is colour-accurate for every creative, technical and archival needs of visual contents. After a general understanding of ACES as a whole, the author will focus on his own contributions to the project: some of the ACES colour-mathematics internals, and aspects of colour representation and transmission as metadata, [3]–[6].

2. The colour chain: faithfully conveying the imagery to the watcher

Image scientists in the video and motion picture world usually call all the algorithmic, electronic and physical steps, and the logic consequentiality of all the passages needed for coding (i.e. encoding, transcoding, recoding and decoding), transporting, interpreting and displaying the colour information of digital pictures as the '*color pipeline*,' [7]–[9]. Pretty much as there are diagrams, blueprints, charts and data sheets for computer networks, digital data movements, access control lists and journey logs, all the colour information needs to be seemingly treated all along the way, from its inception: either principal photography, film scan and full CG.

Taking a typical all-digital pipeline as an example, all the luminous stimuli in a photographed scene are captured through lenses by a digital camera sensor, which records *illuminance* data (lux, EV, stops) and, via digitization/quantisation, get discretely recorded in-camera as *codevalues* (CVs) — usually a tuple of integer or floating-point values (with a fixed bit-depth) per sensor's photosite. The relationship between an image's actual dots and a photosite (which is usually some non-reversible mathematical model of mosaic/Bayern pattern) will not be covered here and assumed to be just one-to-one mapping. The CVs represent just numbers in a camera-specific colour space (partially or completely undisclosed by its vendor).

Most importantly, those numbers should directly relate to the scene's original stimuli; the colour encoding is thus said to be *scene-referred*, [10].
At the other end of the story —where pictures are digitally stored for the last time before being (analog-converted and) presented to the viewer— the CVs are now in a direct relationship with the illumination characteristics (and reflection ones as well, for illuminated sources like paper or projector screens) of the displaying device, which is actuated to reach certain *luminance* targets (cd/m² ≡ nit, ft-L). For this reason the colour encoding of the pictures, at this stage, is usually said to be *output*- or display-*referred*.
At some point of the production chain cinematographers and imaging scientists are concerned about the preservation of scene-referred data as deep as possible *into* the color pipeline, as this allows to retain most of the original luminous stimuli captured in the scene (e.g., during the creative colour correction/grading). Nevertheless, images are ultimately presented on a luminous device and, while preserving scene-referred data may help for future re-utilization of the raw content (e.g archival/preservation needs), a conversion to display-referred data is always in order. Usually, as at least any creative manipulations of the picture are done with feedback via viewing devices as well (e.g. viewing monitors, projectors), content owners and imaging scientists need display-referred data as early as possible through*out* the colour pipeline. This happens not just for the final video mastering, but each time the picture is displayed.
To technically harden the above —which is already an exquisite blend of philosophical, creative, scientific and business reasonings— electronic images are transported by and manipulated as nothing but an array of CVs, i.e. digitally-encoded integer or floating-point numbers: those numbers may only represent scene- or display-referred coordinates in some mathematical colour- or stimuli- *space*, but there is little to no ways to control the actualization of the colours to stimuli, nor the perception to the end viewer (which ultimately both depend on the viewing environment, due to chromatic adaption, and on the viewers' own eye-brain system).
Finally, some technologies (SDI transports, some painting/rotoscoping and almost every non-professional imaging software) can only work with integer-encoded data, where some other prefer floating-point encoding for either better accuracy and GPU rendering. For similar reasons, photometrically-*linear* encodings (where doubling a pixel's CV maps to a twice-as-bright dot) are most suited to computer-generated or -assisted imaging applications (for better mathematical simulation of the environment) than are other forms of "pseudo-logarithmic" encodings (like film scans' or camera-native ones), which are preferred for creative look applications (e.g. colour grading) as well as final viewing. That is because of human perception to light (as most of nature's laws) being logarithmic itself; this also explains why colourists like to work with such "*log*-encoded" images.
In real-world colour pipelines for any professional-grade feature films (which is what nowadays passes by a *Digital Intermediate* process), CVs are manipulated among different of such encodings, in order to comply with quality, creative, engineering (interoperability, storage and bandwidth), standardisation and business constrains.

3. ACES motivations as related to archival and colour management

Colour Management is the set of procedures, instruments and quality-control practices (e.g. colour calibration) that interoperate such that, at each stage of the imaging pipeline, e.g. every output device interprets CVs in the correct manner, and (vice versa) digital signals fed to such devices are colour-encoded in the way the device is expected to interpret them.

While the methods in place to accomplish this are known, have been existing for quite some time (some even before the early days of 35mm-film based Digital Intermediates), and are independent on the ACES framework *per se*, the reality is that, up to now, commercial trends, vendors' different implementations, secret sauces (and the need to keep them secret), together with *either* lack *and* abundance of standards, made things both harder to interoperate, and almost impossible to future-proof — especially in motion picture post-production.

As a first example of such a danger, despite there are a few densitometric digital encoding standards for negative and intermediate film scans, larger film labs (like Technicolor, Deluxe) developed their own ones over the years, both for business strategy and better integrate with their photochemical developing and printing processes. The long-distance result is, however, that digital film scans encoded in non-standardized colour spaces endanger preservation of the film's original colorimetry in case the formulæ interpreting the discrete, CV-encoded film density are lost. It is paramount that archival and preservation is done in open, publicly available, colorimetry and encoding standards (like CIE *XYZ*, DCI *X'Y'Z'* and ACES colour spaces). A second example is the technical constrain that is often faced when a convenient concatenation of hardware/software devices along the colour pipeline (cameras, LUT boxes. creative software, cables, TVs and projectors) is unfeasible because one device from a particular manufacturer does not understand the colour encoding coming as only possible option from the previous device (possibly from another manufacturer).

3. The image interchange framework behind ACES

The AMPAS's Science and Technology Council has been gathering a group of variegate experts from all the top-level production, post-production facilities and software houses in the industry to put forward a solution that unifies all the colour management issues: ACES, [1].

First of all there is the need for a *reference colour space*, which was chosen to be scene-referred. Unfortunately, as neither colorimetric cameras nor colorimetric monitors/projectors exist as of yet, this colour-space choice has lead to reverting to a one within the RGB model, which is more practical as long as ACES pertains with TV and motion picture data. Every colour-correction operators in the involved pipelines (from camera controls, to colour-grading suites, to projectors' and TVs' balance controls) are, in fact, RGB-based.

Version 1.0 of ACES, whose project the author has been cooperating on with the AMPAS experts since 2012, is a framework with centralized colour-management paradigm, where the image is evaluated according to its colorimetric digital representation. Please refer to Fig.1 for a schematic throughout this section. First of all, ACES defines *AP0* and *AP1*: two sets of RGB primaries for the four ACES colour spaces: AP0, whose CIE xy chromaticities are (0.7347,0.2653) for Red, (0, 1) for Green and (0.0001,0.0770) for Blue (which are used in the ACES colour space referred to in Fig.2). AP1 primaries' chromaticities are instead (0.7130,0.2930) for Red, (0.1650,0.8300) for Green and (0.0128,0.0440) for Blue. Both use CIE D_{60} illuminant (0.32168,0.33767) as white-point and physical blackpoint at CIE XYZ triple $\mathbf{0}_3$. Please cfr. Fig.2 for a comparison between the above primaries with other colour spaces'.

Within ACES colour pipeline the image is considered as virtually captured by a *Reference Input Capture Device* (RICD), which is an idealized digital 'camera' recording in a RGB colour space called *SMPTE2065*, which uses AP0 primaries. Again it is important to stress that SMPTE2065 is a *scene-referred* colour space, i.e. the CVs represent mean relative exposures to the ones captured from a perfect reflecting diffuser — apart from a 15% glare. This accounts for a normally-exposed 18% grey card as acquired by the RICD corresponding to the RGB triple (0.18,0.18,0.18) in SMPTE2065 colour space.

Any real camera imagery and colorimetry is brought into the pipeline by means of a colour gamut mapping called ACES *Input Transform*[1], which basically converts all the camera's colorimetry into SMPTE2065. Currently, Input Transforms for most of the patented, cinema-grade cameras like the ARRI Alexa, the RED™, the Sony F*x*5 the Blackmagic Camera and the Canon CinemaEOS™ families, are provided (as either standalone or embedded in the manufacturers' SDKs/APIs), mapping the sensor's proprietary gamut (creatively called ARRI Log.C, RED.Log, S-Log, BMDLog and CanonLog respectively), parametrized by shooting settings like equivalent sensitivity (ISO) or correlated colour temperature (CCT), into scene-referred SMPTE2065 CVs.

The author has also been active in Italy for promoting the use of ACES with several initiatives, including a real-world, on-set test to compare ACES framework originating from different, high-profile cameras, up to a full VFX and Digital Cinema mastering pipeline. Figs.3–5 are the result of a technical photography session where three cameras where compared and footage from all of them brought into the same ACES pipeline.

At the other end of the pipeline, SMPTE2065 colorimetry is converted to the gamut of the displaying device by means of an ACES *Output Transform*[2]: there are two, for example, for Digital Cinema mastering (in either the DCI P3 colour space using D_{65} illuminant as white-point, and a variant of it using D_{60} instead), one for standard broadcast TV (ITU-R BT.709), one for standard PC monitors (sRGB), one for UHDTV (ITU-R BT.2020) spaces, and so on. From a Colour Appearance Model (CAM)'s perspective, the Output Transforms take care of the viewing environment as well: so several Output Transforms may exist for the same device, with expected exposure in different chromatic adaptation environments.

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1 It replaces what was the *IDT* (Input Device Transform) in pre-1.0 ACES.

2 It replaces pre-1.0 concatenation of the *RRT* (Reference Rendering Transform) which converts scene-referred RICD CVs into *RDD* (Reference Display Device)'s display-referred CVs, with the *ODT* (Output Device Transform) which converts into the final output device (and/or output colour space)'s colorimetry.

All in all, SMPTE2065 space uses AP0 primaries, has *trivial* transfer characteristics (it is photometrically linear, i.e. "*gamma*-1.0") and represents the baseline for all the ACES pipeline — and the widest gamut as well, which is also suited for long-term archival, cfr. Fig.6. Code-values are usually encoded as 16 bits/channel floating-points ('*half-floats*' as per IEEE 754-2008 standard), and archived in a specific frame-per-file uncompressed variant of the OpenEXR file format, cfr. [11]. All of this is already part of SMPTE Standard 2065-4, [1], which the colour space borrows the name from.

It is within this colour space that images are worked on, with exceptions when it is technically convenient or mandatory to use *temporary*, well-defined colour-spaces for specific purposes, as introduced in §§67–69. ACES thus defines additional spaces:

- *ACEScc* has AP1 primaries, "logarithmic" transfer characteristic, 32 bits/channel float encoding optimized for film-style colour correction, [12];
- *ACEScg* has AP1 primaries, photometrically-linear, 16 or 32 bits/channel integer code-values, optimized for CG and painting software applications that barely support floating-point CV encodings, [13];
- *ACESproxy* has AP1 primaries, the same logarithmic characteristic as ACEScc, 10 or 12 bits/channel integer encoding, optimized for real-time transport of images over physical links (e.g. the SDI cables) that only support integer code-values, yet logarithmic encoding is still needed for on-set colour correction applications, [14];

ACES clips are stored in frame-per-file ordered sequences, encoding each frame as a OpenEXR file [11] (usually with every clip or consolidated asset represented as individual OpenEXR file/frame sequence in a dedicated folder), together with ACES-specific metadata optionally written in a "sidecar" XML file called *ACES clip-container* [15], which is transported along with the video file(s) it references.

Ideally, any sensitive colour operation (both for technical and creative intents) should take place in either the SMPTE2065 or the *ACEScc* colour spaces (which act like a PCS in the ICC paradigm), where any operator acts unambiguously. Creative-intent operations, in particular, are stored in the so-called *Look Modification Transforms* (LMT), which are applied before the Output Transform(s).

6. Transportation of Colour information and pipeline

The colour pipeline within ACES 1.0 ideally allows to transport the colour metadata either separately from the images themselves (at least as far as colour science mappings of technical nature, and *primary* colour correction, [3]) or burned in the image CVs: whatever is the case though, a record of the clip history, is stored within the clip container, so that every ACES-compliant application managing the ACES clip is capable of interpreting it within its intended colour space and at the right stage of the colour pipeline. Future versions of ACES will even include the clip's past applied colour transformation(s) within the clip-container, so that a complete history of the clip —or "color-*pedigree*"— is preserved for even better fidelity. This is particularly true for the LMTs (cfr. §2); there can be more than one LMT applied, which is why their order and context is extremely important for interoperability across devices and products from different vendors. An LMT can either be described as a primary colour correction by a floats' 11-ple representing an *OSCARS*®-winning American Society of Cinematographers's *Color Decision List* (ASC *CDL*, [16]), or by means of a ColorLUT (CLUT, cfr. [3]–[5] and Fig.6), and is usually stored in another XML file called CLF (*CommonLUT Format*). Most of these file formats are defined as either AMPAS and SMPTE standards.

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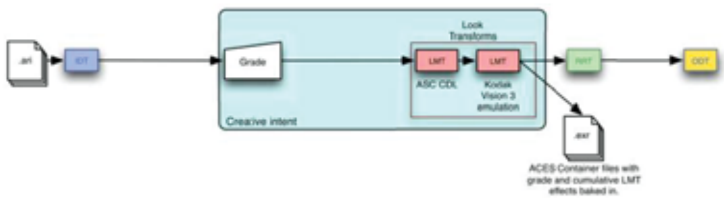

Fig. 1 – Sketch of the ACES paradigm: the original scene is either captured by a real camera or generated in CG. Whatever the source, the corresponding Input Transform converts the CVs into the SMPTE2065 colour space (except for the "ideal" RICD, which already produces SMPTE2065 pictures). Using the Output Transform the pictures can then be transferred to any output devices, like monitors (with any technologies), projectors, TVs, etc.

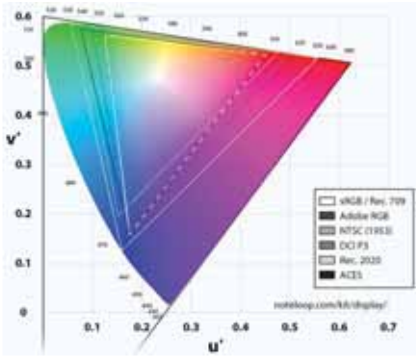

Fig. 2 – Chromaticity comparison between ACES (SMPTE2065) gamut and other well-known RGB colour spaces.


Fig. 3 – Real-world comparison test footage on the same technical set from cameras: ARRI Alexa XT (*top*, Log.C colour space) and Sony F55 (*bottom*, S-Log colour space). Courtesy of DIT Emanuele Zarlenga.

Fig. 4 – Footage from Fig.3's set (Sony F55 camera), after applying the Input Transform *and* an LMT into ACEScc colour space for the purpose of colour grading (washed out look is due to the tone-curve behaviour of the RRT).

Fig. 5 – Comparison footage from Fig.3's set, from cameras: ARRI Alexa XT (*top*, as in Fig.3 top), RED EPIC (*centre*) and Sony F55 (*bottom*, as in Fig. 3 bottom, same as Fig. 4). This time only the respective Input Transforms were applied into the ACES SMPTE2065 colour space. Photometric linearity accounts for darkened transfer characteristics rendered on both paper and video).

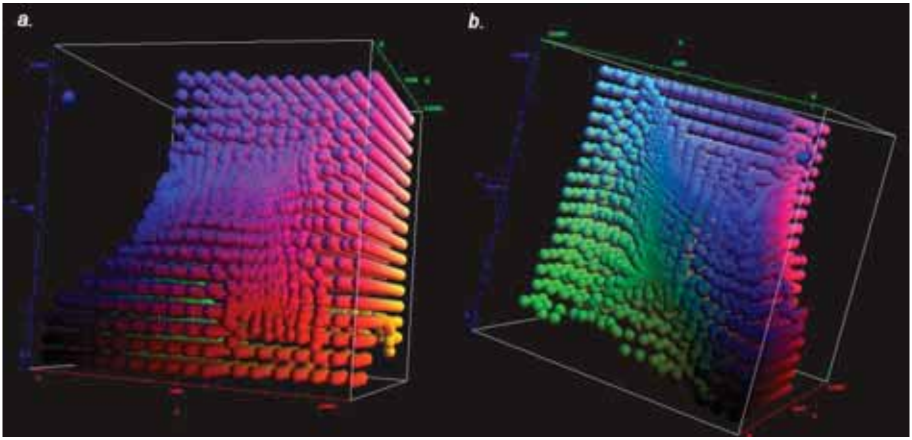

Fig. 6 – RGB-cube (tensor-like) visualization of a *print-film emulation* 3D ColorLUT, which is another type of technical colour mapping that can be described in a LMT.

Role of color in designing local containers of Gilan inspired by local clothes and folk music of Ghasem Abad region

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Abstract

Ghasem Abad is located in far east part of Gilan province in north of Iran and it is globally well known for its local dress, dance, folk music and beautiful landscapes. The role of color and design and happiness in dance and dresses of Ghasem Abad is a prominent sign of the culture in Ghasem Abad region which distinguishes Ghasem Abad from other regions of Gilan province. The features of GhasemAdadi dance and colorful dresses have brought it many valuable prizes from international festivals around the world. Since rich culture of Gilan has symbols and signs in different dimensions, it has been reflected in food traditions of Gilan people which is more variant compared to other places of Iran and that is why Rasht city has been selected and registered as the city with the most creative food variety in "intangible heritage" list of UNESCO.

Interest in design of containers, as a sub-field in industrial design, and also limitation of traditional containers available in Gilan and the need for creation of new containers with local identity for serving almost 170 types of foods in this region with new and unseen designs and combination of these products with symbols of folk music in which the role of color is prominent is the main cause of this comprehensive study about cultural signs of Gilan to make and create new designs for reflecting the authentic and traditional art.

The main objective of this study is "applied recognition of aesthetic elements of culture of Ghasem Abad - Gilan as one of the prominent types of culture of Iran and reflect it in design of containers for variant foods of that region". The study was processed in a manner to make the concerned product as the cultural messenger from Ghasem Abad - Gilan. So, library and field studies were launched and pictures and tables related to the concerned product and its various applications were registered. The study was completed by studying the history and geography of the region, collection of various traditional containers, symbols of nature and architecture, life style and customs of Gilan people and also observation of the application of the containers and interview with manufacturers of local and traditional containers as inheritors of this culture.

Based on this study and its results a emotion-oriented approach was used. The results will be presented in 2 theory and practical sections.

Key words: Gilan, GhasemAbadi dance and dress, emotion- oriented design, local containers

Introduction

The Iranian rich culture is full of significant samples of design in different divisions especially crafts. This region offers products with different identities in many practical fields because of its extensive rural and civic context which each of them is unique in itself. Undoubtedly, these products due to their constituents could be used in homes and other public spaces as decoratively and practically. But redundancy and lack of consideration to product nature caused to decrease the visual and emotional effect and gradually it has be seen most often and called repetitive. This product doesn't place the user as incentive position to use and purchase product and gradually the society will encounter many products which have no any word to say. This is so important in products which are introduced as traditional products in region. These products have not only nativeapplication, but also are considered as elements which are represented the native identity to others. Considering the design principal of these products can present the native culture and values as impressive form and inspired by the natural elements of region and due to the concepts transfer special visual and emotional message, it moves toward improvement of this industry. This study intends to see the traditional dishes of Gilan in new look and emotionally tries to provide design of these dishes in new method to be a context to introduce the culture of this region nationally and internationally. Even a small object can be represented a part of Gilan's paradise.

Gilan province

Figure 1: http://culturalmanagement. parsiblog. com

Gilan is mentioned as Varene in Avesta(holy book of old Persians) and it was the ancient center of different tribes which most famous were Gil and Deylaman . Greeks called this land as kadoosian. Some authors considered Kadoosian as Iranian native people before arrival the Aryan to this land. As the Russian author,Diakoov, said:" About 3000 years before, the wood lands of Caspian ,Kadoosian and Gilan (Gils) located in north of Mad territory . Gradually, Gils and Kadoosian became as a unified family."

Gilan developed significantly at the end of the Qajar era and became the gate toward Europe. The big orientalists mentioned Gilan and lands in south coast of Caspian Sea with three thousand years of civilization and some of them mentioned the existence of a big civilization in Amlash and Deylaman[1].

QasemAbad : it is one of historical and noble village in Iran , located in east of Gilan as a division of Roodsar township . This village composed two parts: the higher Qasem Abad and the lower Qasim Abad. This region has certain cultural specification and reaches the international reputation because of its special cloths and dance.

Qasem Abad clothes: these clothes are the most ancient clothes of Iran and orient land which won different awards in international festivals of fashions and clothes. Clothes of Qasem Abad women is so famous because of high color variety and attractiveness so that signs of this clothes could be seen in other regions of east plain of Gilan . Its skirt is made of simple cloth or with flowers designs which sewed some ribbons as a standard form on it. Of course this ribbon form is changing in different villages and in fact it complements the party clothes in neighbors' villages. The researchers believe the history of these clothes design is more than four thousand years before.

Figure 2: Qasim Abad clothes , source: author

Chadorshab: Gilanresidentsbeautifulclothes istraditional clothes in Qasem Abad andtheladiesof this areause Chadorshab asbackcover. The maincolor isredandthe background of Chadorshabis so strong inQasem Abad, sothateverybrideshould haveat leastonecolorsilkChadorshabasherdowry.

Figure 3: Chadorshab, source: author

Chadrshabuses: bed linens, pillowcases, table cover, backcover, bed coverage, curtainsand...Mostusedcolors areorange, red, yellow, and generally vibrant andalive colors. Ithassubjectivedesignsandbased on theofobjectsandanimals, some of whichinclude themonth, horseand horse rider, comb, flowercarpets, shuttle, chandelier, dart , antelopes, birds, chickenandlamb [2].

Figure 4: Chadorshab role in women clothes, source: http://www.karkan.ir/

Changes of clothing and decorative stitching on it , are also worth attention, not only in terms of history and art, but also to understand the perspective of sociology and psychology of nations.

Gilani men and women wearing different types of beautiful clothes have unique traditions; Gilaniwomen make beautiful clothes for colored fabrics. Using ribbon embroidery, applique and embroidery on clothing coins are common in different parts of GilanespecialyQasemAbad ,Roodsar and Deylaman and Masal . GilaniWomen have significant skills to weave silk scarfs, wool and silk socks with traditional and interesting designs and vivid, beautiful and amazingcolors [3].

Figure5: Qasem Abad clothes- source: author

Color and sensory abilities of products

One of the driving factors of the conceived physical world around man is color. Colors used in products and environment around human can be expressed thecriteria of social position, standards and sensory perception of colors associated with conditions. Special specifications of objects and products can be expressed by using colors and sensory perception of them. Emotionaldesign about the color does not follow a specified pattern, but the pluralism that is seen the transparent to the primary and supplementcolors and are the stimulating factor for human feelings and transforming one of the different meanings [4].

Culturaldesign

Designersunderstanding of theculturalcharacteristicsof asocietycontribute to change values frameworks and to create productsforuserswith full of

sensoryexperiences(cited from theMoalosi site) [5].
Every culture, according to its own specifications create some artifacts and these artifacts caused to create a new culture in society, hence the creation of artifacts needs to comply with the conditions, customs, beliefs and rituals of the society (cited from Sato site) [6].
Culture plays an important role in the design and in the near future , the cross-cultural design will be considered the basic point in the evaluation of proposals. Product design based on a culture has become a taste, style and trend in the design world. Obviously the designers have a deep understanding of cross-cultural communication not only to success in global markets but also to more acceptances by users in the same country. While , cross-cultural problems are among the most important subjects to design products in world economy market , the cross point of culture and product design is a significant issue in production process of every market and this caused to very deep studies in this subject [7].
According to the basic approach of this paper, as emotional approach and its compliance and alignment with cultural design, which represents a case study of Gilan, it is discussed the full definition of emotional approach.

Emotionalapproach

feelingschange our way of thinking and always guide us. Now feelings play a major role in the design and the superiority of function than appearance is rapidly changing. Research in recent decades has shown that humans not only use a product (industrial or cultural) but also to establish an emotional connection with it.
reaction against objects is raised in three levels, instinctive , behavioral and thinking.in other words, their response can summarized in three question: do I love it? (instinct) [2] 2.Does it work? (logic) and 3. Will I use it again? (experience and culture).
Designers have found that people tend to portray human feelings and beliefs by imitation of everything. On the other hand, imitative reactions may provide the joy and pleasure for the use of the product. If everything goes well and emotional structure shows a positive reaction, so it brings joy to user. Similarly, if a design is beautiful and joyful, the emotional structure reacts again.
The products can be more than a set of functions that they perform. They can satisfy the emotional needs of the user. Product that has intellectual value (reactive) and represents originalityis one of the symptoms of a cultural product [8].

Indigenous and traditional dishes ofGilan

dishes or container is referred a place to put something in it. Utensils are usedin cooking ,kitchen and serving food extensively. (AsgharZhianDarbandi,, the Iranian hoteling website) Darbandi, AsgharZhian, "dish on the table in the hotel" Iranian hoteling website [9].
Utensils and its application have a very long history and dates back to prehistory. The world's oldest pottery dishes have been found in Mesopotamia and Persia (from the fourth millennium BC). At the same time, same dishes were also found in China. "(a glance to the history of pottery handicraft, tafahom newspaper.") [10].

The most common traditional Gilandishesis called Gamaj which is used to cookstew .It is made of clay and baked in the kiln .It has enameled insideand outside and used to cook food. Even now some families still use this type of Gamaj to cook stew on a gentle flame, so this caused to cook a deliciousstew. It is in various sizes(small and big) the shape of this container is a circle, and its manufacturing method is also circular. (JalalJafapour, Spring 2008) [11].

Figure6: source: author

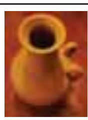
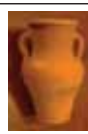
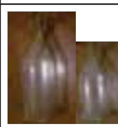
 Gamaj Satoortakhteh	 Somapelan Gamajdaneh	 Ghandehlak
 Gamaj	 Teyan	 Somapelan
 Nokhoon	 Kase	 Spoon
 Narkheh	 Teyan	 Chire
 Tabeh	 Moshrafeh	 Mastehkooleh
 Namakar	 Aftabehlagan	 Haftayeeyee -Chardahtayee

Figure7: Some of traditional and indigenous dishes are among utensil in Gilan people’s kitchen

Food culture in Gilan

One of the striking aspects of cultural understanding is awareness of the various elements of its food culture whichis perhaps the most obvious indicators that could represent customs, attitudes, habits, literature, geography, and public taste. Diversity in food represents knowledge, creativity and art of its creators and community spirit that has been fed these different foods will benefit from a wider perspective of the taste experience, and perhaps, this add the sensitivity of people faced with a life flavor and taste. "Food culture of the people of Gilan" book* is being developed by the author with the introduction of its different dimensions, has tried to reflect the richness of the culture at large, which is a bilingual collection, in addition to recording the eating habits in order to maintain and transfer these habits and it also offer new ideas for food, Gilanifood table layoutin different colors and designs , seasonal foods , serving style in different regions, the introduction of local markets, local products, traditional dishes, as well as design of Gilan local dishes by cultural and emotional approach. Because according to all that was said, the vacancy place of Gilanlocal dishesis clearly seenthan variety of unique food culture of this territory [12].

Figure 8: Gilan table-Dadgar magazine No26,34-design, cooking, arrangement and photo : author

Figure 9: Gilan table-design, cooking, arrangement and photo : author

Also based on observation traditional kitchen in Gilan, daily use ofutensil compared to most traditional dishes (Gamaj), tend to use the traditional dishes in the target group especially when cooking local foods, and food serving into the non-local dishes in all restaurants inGilan, matching recipes with suitable containerstypes of cooking books and the lack of using native suitable utensil for the introduction of food culture inGilan, and attention to the lack of suitable product design (utensil based on a variety of over 170 types of foods in Gilan and etc was the incentive to show an attractive part of the culture of Gilan, and its harmony with nature and openness of this culture than other cultures to reflect the hospitality of this culture, all details have considered in product design and has been as reasons to design indigenous and traditional dishes in Gilan.
Also it is worth noting that, none of the dishes sampleson the market had anydesign of Gilanfolklores. The following results are obtained from the users of Gilan local dishes about cooking utensil : They consider foods in these dishes more delicious because of clay nature in these dishes which needs more time to cook foods in them.They saw very little variety in foodutensil and there was not remarkable example for tea set in market.
Another part of the field research and interviews was done with knitters and weavers of Chadorsahb in Qasem Abad and has also completed a questionnaire by target group about design and production of utensil, their proposals were as follows: Most of them advised to Iranian designer to design and product in regard to Iranian identity .According to their tendency to the northern part of the country and the Gilanprovince, they have viewed local products and handicrafts of the region as steady products. They needed the new products with different style rooted in the distant past. Diverseproducts to be presented as a gift and the identity of the individuals in the family can contribute in it and even production of customized utensil for foods and tea set were focused.
Due to all above mentioned notes to design Gilan local dishes, a set of five parts as cup, saucer, small plates, plates and soup dishes were designed. Due to product presentation method, each of dishes can be supplied individually because of design nature inspired by Gilan culture, dance, joy, colorful clothes of Ghasem Abad, morality of people in this territory, adoption of it to the idea of Donald Norman in his book named emotional approach, based on customization of product, designing the personal products and making changes in products by using color diversity, form adaptions and usability of design individually. For example, it is possible to use a cup or saucer in one set rather than other setin spite of different color diversity in beautiful and splendid look. This idea is rooted from hospitality culture, communication with another world, diversity in colors of clothes and a sense of Qasem Abad joy and excitement in dance and dress.
Interest in the personal world and maintain personal privacy, individualinterests with the desire to be in public and social life, work culture in Gilan, that the men and women working side by side with each other, caused a product with colorful variety in dishes set for a family of five in order to coordinate the collective life, along with a family visit and the role of objects (containers) in this interaction will determine the independent self- identify of individuals. If a family member is absent at table, his/her personal dishes will remind his good sense while family

havemeals.De to the color diversity of products, in first schema , the green color is consider inspired by the green nature of Gilan. In the second scheme, according to theGilani taste of the food, who desire to taste sour food and sour pomegranate water or sauce are used, so white cup with pomegranate flower paintings were designed, colorful plaid stripes as green, white and red, in both schemas with a design of a node under the cluster of cup and soup container were inspired designs of Qasem Abad women's Chadorshabclothing, the saucer, small plates and plates were designed with white body and pomegranate flower paintings, as well as one-third of the dish designed inspired by Qasemabad skirt trimmed with light and dark green, red and white stripes .cup and tablespoon forms designed for both schemas in body like the crease lines that suggest Qasem Abad women dress shirts, and form of saucer, small plate and the plate with uneven curves is associated of Qasem Abad women skits during their dance in above view . In bothschemas, due to the green nature of Gilan (green color) Chadorshab tissue (red, green) and Pomegranate Flower (red) and complementary colors are placed next to each other. The traditional dishes made from clay by hand as well as the majority of food products are made by hand,so manual manufacturing methods have been selected for this product.

Figure10: source: author

According to the author search of container products in the market, it has not been found a sample which represents the above elements due to the characteristics of indigenous and traditional cultures of Gilan, which the most prominent symbols of it areQasemabad women's clothing and dance. AlsoGilan nature have different potentials in different contexts, colorful joys of music, dance, colorful clothing in Qasem Abad, , which along with other mentioned cultural elementshighlight the specific characteristics of cultural expression, which is one of the best other symbols of Gillan to present indigenous and traditional culture of this area in which colors play dramatic role.

Figure11: products in different colors-source: author

Human has long been influence the environment colors and he was sensitive to color and has a lot of color in various fields. In addition to color plays significant role to make communication and messaging, in different societies used as a symbol of emotional, cultural, ethnic or national. Industry gradually discovers that colors have a more central role in processes of design to produce, people also need more punctilious, so that they see the colors in terms of product design. This public awakening makes a space which can be felt in design process to show materials. Human has been affected colors both physically and psychologically. Obviously, the color effect on human has psychological nature and influence on norms, actions, reactions and behaviors indirectly. The sensory images, including images, sound, smell and even physical touch, they can be reminder of the reality of the memory, so the memory recovery process happens with amazing intensity. For example, jade green, which usually leads to the revival of traditions and memories of the dependencies in many consumers. [13]

Choice of colors, to reflect the color and joy, in the design of Gilan local dishes, inspired by the costumes and dance of Qasim Abad, is in accompany with beauty with the color of local foods. Foods that often have an international reputation and their main constituents are most plants. Gilani table experience, with the richness and color has been the most memorable experience of tourists traveling to the Gilan. Food colors: green (Baqalaqato stew, pickled vegetables, sour chicken, garlic fricassee and squash, sour soup, , etc.), yellow (Chagharatmeh, Cui soup ...) yellow and red (Mirza ghasemi) red (pomegranate stew, sour kebab), orange (salted fish caviar), brown (Avij pomegranate stew, Eurasian Teal Fesenjan, etc.) beside white cooked rice with brown end part of rice (rice cooked the way of North), which is usually served with all meals. Condiments such as, Cal barbecue and processed olive as colors green and pink along most of the food is used as the image for food of Gilani's identity. As well as many other foods are accompany with to the beautiful colors of choice in the design of the container.

Sort of colors for this design are based on complementary colors, which are located right in front of each other in the color wheel and create the highest contrast and stability. And their selection influence psychologically, which are designed to transmit a message.

Psychological effect of green color makes the person feel even closer to nature, and also transferred others the feeling of comfortable and more relaxed. Using this color as a fertile soil cause to make a rich world for person .This color naturally make a kind of harmony and encourage person to listen his inner sound to find what he needs to enjoy more comfortable himself and others . Red color makes a power to speak about what you think frankly. And the psychological effects of the white are transparency, purity, cleanness and simplicity [14].

Undoubtedly, the international popularity of Ghasem Abad folk costume, which has been a source of inspiration for this design, along with the specific forms of clothing, influenced by the colors used in it.

On the view of the writer, the earth and its creatures representthe creation art of God. The existence container and the presence of the different worlds in itcombine the roles of man and the will of God. The role of the designer to understated man and the Creator can be seen the creation of objects such as dishes.

Consciousness is a phenomenon so that designer discovers the wonders of God's art andseeks footsteps of this art in subconscious aspectof human life and surroundings. Then the numerous steps would have gone along with nature to represent a sign of this flexibility for coexistence in the world.

Peace and friendship between peoples and nations is possible with an understanding of each other's cultures and every step is taken to introduce different cultures, peoples and nations to help the association.

Author with this issue tried to take a step in this direction. At the end of this article, he would be pleased to be able to introduce some parts of Gilan culture and beauty of this city and its people, to join this association.

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Application of colour local pattern in colour texture images

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Abstract

The Julesz's conjectures were the foundations for the development of many methods for texture discrimination as spatial arrangements of local patterns. These local patterns represent a bridge between a first conjecture that handles a purely statistical approach and the texton theory, which is the enhancement of this conjecture toward a structural approach. However, the two levels of decomposition in local patterns processing involves a lack of information. Colour Local Patterns (CLP) is a new vector used to characterize texture and colour for texture discrimination. CLP is based on local binary patterns (LBP) defined by Ojala. By defining the CLP in a perceptual colour space and by using a perceptual distance, we embed the notion of neighbourhood defined by Julesz and used in LBP. Then by applying a Fourier transform, we generate a signature vector for the local signature. The results achieved in classification tasks are higher around 10% in the rate of good classification in two databases with the largest number of images.

1 Introduction

The human visual system (HVS) processes the visual information by extracting the salient regions from their local contrast in the perceived sense. In this process, the information of texture and colour take an important place [1].

There are two functionally different visual information-processing systems. The first one, the pre-attentive system, is in pre-conscious level and without the help of cognitive process. The second one, the attentive system, involves search, research and cognitive processing. The pre-attentive system separates the regions of a figure with the background, acting thus as a guide for the attentive system which is responsible of object identification [2].

There are many theories to set the way in which the human visual system encodes the structure of an image in the pre-attentive system [3]. Julesz in the first conjecture proposed it, by means of differences statistics of first and second order that contribute at the discrimination [4]. Later he wide this conjecture: "whereas textures that differ in their first and second-order statistics can be discriminated from each other, those that differ in third-order or higher order usually cannot". More complex relationship information's are required to solve these limits [5].

The second part of the Julesz's work with Caelli established that the textures are easily discriminable by a number of geometric properties as local curvatures, endpoints and junctions called "*perceptive quarks*" [6]. After, Bergen and the same Julesz expanded this definition in the texton theory. This theory stated that discrimination is due to the first-order statistical difference between textons. Textons are generally reduced to segments of lines with specific length, orientation, width and gap, as well as terminations, crosses and blobs [7].

The foundations of texture assessment by image processing tools started with Haralick, who translated the purposes of Julesz into the co-occurrence construction [8]. Since these works, lot of methods were developed for intensity

images, to express the texture information into digital features (histograms difference, co-occurrence, run-length matrix, Fourier transformations, local binary patterns,…). However, the extension to colour images is not straightforward. The first constructions followed the Poirson and Wandell's hypothesis [9] proposing to separate the colour information from the texture [10], [11] and [12]. Nevertheless, such hypothesis is too basic in front of the spatio-chromatic complexity of natural images. So Palm's proposed to process the texture information on each colour channel and to combine them into a single texture feature, then Arvis in parallel with Palm proposed to extend the construction to the inter-channel texture information [12], [13]. Finally Martinez Ríos et al. shown that the right colour texture model depend on the inner spatio-chromatic complexity of the image. Consequently, they extend the basic approaches separating the colour and the texture to the vector models including naturally the two aspects [14], [15].
Our work proposes to show how the initial texture features for grey-level images can be extended to colour domain in a vector way, using colour and perceptual distance functions. An extension of Local Binary Pattern in the vector way, with improving their limits of binary elements. This paper is organized as follow: In the section 2 the mathematical definition is showed. We analyse the graphics of Colour Local Pattern (CLP) before classification task in the section 3. Finally, we present our results and comments in section 4.

2 Local binary pattern

Local binary pattern (LBP), proposed by Ojala et al. [16], was developed for texture recognition and classification of grey-level images and adapted for colour images [17]. The original algorithm presents a low computational complexity and a low sensitivity to changes in illumination [18]. Due to the initial construction, LBP presents a bridge between statistical models and structural models of texture analysis [19]. Therefore, Huang defines LBP as the quantification of the statistical occurrence of individual patterns invariant to rotation corresponding to certain micro-textures on the image; consequently, patterns are considered as detectors features [20]. LBP approaches have been proposed originally for texture classification but applied also for face image analysis, image and video retrieval, environment modelling, visual inspection and biomedical image analysis [20], [21]. The initial mathematic definition is divided in two parts, first one extracts from an intensity image the local binary patterns and the second one calculates a pattern histogram for texture discrimination purposes [21]. In the following, we recall these two steps.

2.1 Definition of Local Binary Pattern

The local pattern $T_{P,d}(x)$ is defined at the x location by sequence of local differences between $I(x)$ and the neighboured values $I(p)$. The neighbourhood is defined for a spatial localization x, considering a set of P neighboured pixels at a distance d from x:

$$T_{P,d}(x) = \{(I(p) - I(x)), \forall p \in [0, P-1]\} \tag{1}$$

$where\ p = x + d\, e^{ik\frac{2\pi}{P}}$

2.2 Local binary pattern histogram

Ojala works with histograms of words H_w^d for texture characterization where the word $W_i^d(x)$ is the binarization of the local pattern. The equation 2 shows a *weighting* in power of two and a summation.

$$W_i^d(x) = \sum_{p=0}^{P-1} Sign(I(p) - I(x))2^p \tag{2}$$

$$and\ S(c) = \begin{cases} 1, \forall c \geq 0 \\ 0, \forall c < 0 \end{cases}$$

The texture signature is defined by the histograms of words explained in the equation 2.

$$Sig(I) = H_w^d(I) = \{prob(W_i^d = a), \forall a \in [0, 2^P - 1]\} \tag{3}$$

3 From the colour extension

The colour extension of LBP into the colour domain is classically developed in two ways, the first one split the colour texture into a texture information processed from an intensity image and combined with colour statistics (grey-level approaches with colour information, GLACI). The second one process the colour texture thanks to grey-level texture features through marginal approaches separating each colour image in three channels (*C1, C2, C3*) or assessing the intra and inter-correlation between channels (cross-channel marginal approach, CCMA). In this last case, the corresponding distributions are thus represented in nine different histograms: three intra-component features: *C1-C1, C2-C2,* and *C3-C3* and six inter-component features: *C1-C2, C2-C1, C1-C3, C3-C1, C2-C3* and *C3-C2*. Consequently a colour texture is characterized using LBP by *9* histograms of 256 words [10]. Porebsky proposed a method of feature selection to reduce the size of the resulting vector and to improve the good classification rates [22].

3.1 The CLP mathematic definition

Be the circular neighbourhood sequence defined by the vector colour difference $\vec{s}(k)$ calculated in a colour space like CIEL*a*b*.The circular neighbourhood is sampled by a factor *P* to manage the discrete angular θ:

$$\vec{s}(k) = I_L(p) - I_L(x), \forall p \subset [0, P-1] \tag{4}$$

$$with\ p = x + d.e^{ik\frac{2\pi}{P}} \Rightarrow \theta = k\frac{2\pi}{P}$$

In the equation 4, $I_L(x)$ is the transformed coordinate of $I(x)$ in the adapted colour space (CIE*a*b*). To define an efficient feature from the $\vec{s}(k)$ sequence, the Fourier transform $S_{P,d}(\theta)$ of the sequence $\vec{s}(k)$ is processed. To stay close from known LBP standard, the vector construction of this difference was built in two parts, first one considers the norm of this difference using a perceptual distance in an adapted colour space. The second one considers the orientation of this difference in this adapted colour space. Consequently, the Fourier analysis of the difference pattern was developed on three scalar values expressing the vector nature of the sequence $\vec{s}(k)$: a norm and two angles (to see equation 5).

$$\vec{s}(k) = \begin{cases} |\vec{s}(k)| = \Delta E\left(I_L(p), L_L(x)\right) \\ \llcorner\vec{s}(k) = \llcorner\left(\overrightarrow{Oa}, \overrightarrow{s(k)}\right) = \left(\alpha(k), \beta(k)\right) \forall p \in [0, P-1] \\ and\ I_L(x) \ \in CIEL*a*b* \end{cases} \quad (5)$$

3.2 Colour Local Pattern feature

The main interest of the Ojala’s construction for LBP was transform the distance between texture signatures into a distance between histogram of words. In a similar manner, the distance between CLP feature will be based on distance between distributions coming from the Fourier transform of the norm and angle of $\vec{s}(k)$. In a first consideration, we limit the CLP feature to the norm of the Fourier transform of $\vec{s}(k)$ (equation 6).
We kept the square of the norm for to be in connection to a power measure, thanks to that the first feature value (V=0) express the average colour distance between the pixel location x, and the pixels values on the neighbourhood.
In addition, as *s(k)* is a real function, we can store half part of the spectrum.

$$sig_{clp\Delta}(I) = \left\{\overline{(S^I_{P,d}(V))^2}, \forall V \in [0, P/2]\right\} \quad (6)$$

4 Results and Discussion

4.1 Dataset and graphics results

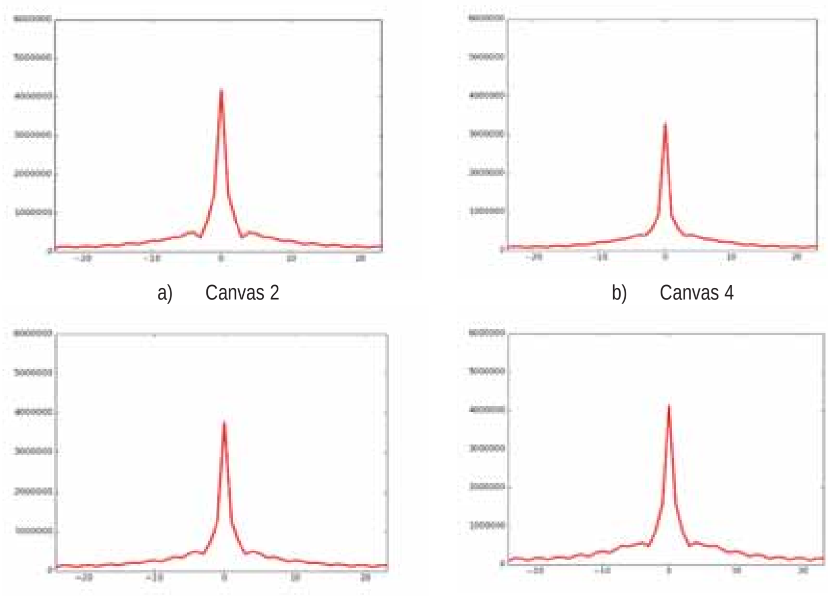
This sub-section presents some average texture signature processed from the vector Colour Local Pattern (CLP) in some images of *OUTEX*, *VISTEX*, *STEX* and *ALOT* databases.

a) Canvas 2 b) Canvas 4 c) Canvas 20 d) Whool 4

Fig. 1 – Some images of colour texture from OUTEX test. There are 68 images; they were taken in the same illumination conditions. Almost all are the same texture distribution.

The physical and perceptual constraints in Julesz conjecture on spatial distances require to work with Euclidean distances to produce an anisotropic analysis. So to preserve the circularity constraint induces by the Euclidean distance and taking into account the requirement of a small distance, we selected a radius of *3* pixels, approximating the circle by an octagon of *16* pixels (*d*=3 and *P=16* in equation 4). Such a choice allows also to be in concordance with the FFT requirements.
OUTEX test is the "*TC 00013*" with *68* colour texture images of *746x538* pixels of *24* bits. Following Arvis for the classification process, images are split up into *20* disjoint sub-images of *128x128* pixels producing *20* sub-images. Each initial image is associated to one class, the complete image set generates *1360* sub-images, 50% for to learn and the rest for classification. The figure 1 shows some images of this database and the figure 2 the associated CLP signature.

The magnitude of the signature for the null frequency is relative to the average distance in the local neighbourhood. More important is this value, more homogeneous is the texture content (*canvas 2*). Without logarithmic weighting, the magnitude variations far from the null frequency seems reduced, nevertheless the texture differences appeared for these frequencies (*canvas 20* vs *whool 4* typically).

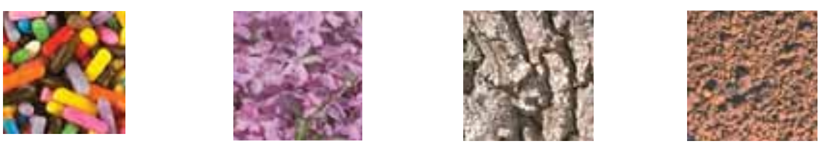


a) Canvas 2 b) Canvas 4

c) Canvas 20 d) Whool 4

Fig. 2– Colour Local Pattern amplitude from *outex* test.

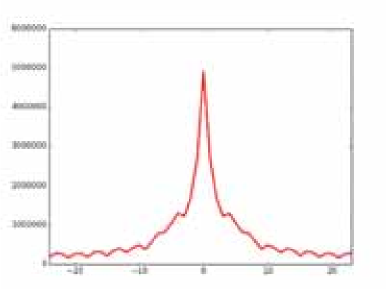
VISTEX test is based on the image set labelled "*Contrib TC 0006*", with *54* colour texture images, whose initial size are *512x512* pixels. Similarly that in outex, the images are split into *16* disjoint sub-images of size *128x128* pixels (to see the figure 3). Thus *432* images are used to build the learning subset and the *432* remaining are used to build the classification features vector.



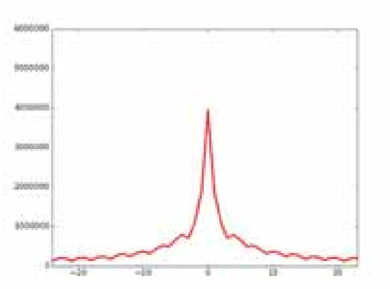
a) Food b) Flower c) Bark d) Fabric

Fig. 3 – Some images of colour texture from *vistex* test. The 54 images don't have the same illumination conditions, some of them are very textured, the others ones are coloured.

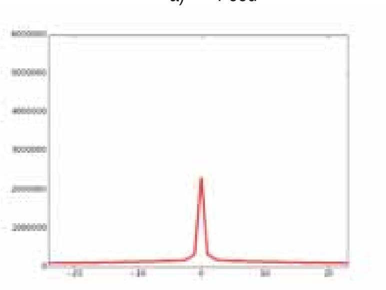
Unlike the *OUTEX* database, the signature variations between texture are more important reflecting the variety in colour and texture of the representative images (figure 4). In particular, the CLP magnitude of image *fabric* is more important than the other three. By contrast, the graph corresponding to the figure *bark* has the lowest amplitude and minor variations outside the centre frequency. In this last case the small spatial distance (d=3) explain these reduced texture variations.



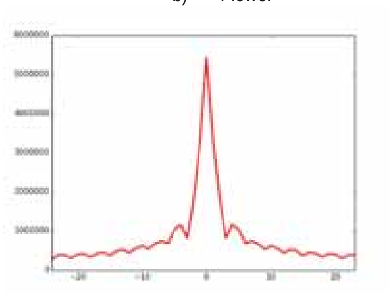
a) Food



b) Flower



c) Bark



d) Fabric

Fig. 4– Colour Local Pattern amplitude from *vistex* test.

STEX database is based on the image set labelled "Salzburg texture image database". It includes *476* colour texture images, whose initial size are *512x512* pixels; the web site didn't describe the acquisition conditions.

a) Bark 01

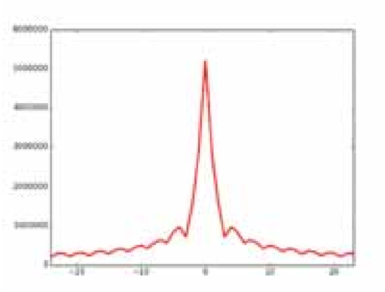
b) Bush 08

c) Tree 05

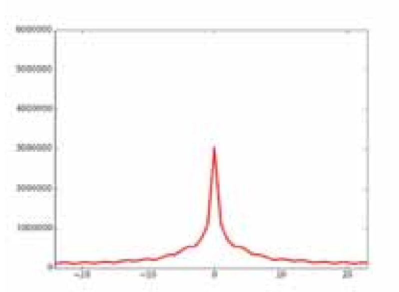
d) Wood 30

Fig. 5 – Some images of colour texture from *stex* test. There are images 476 with many variations in colour and texture. The web site didn't mentioned the condition under the images were recorded.

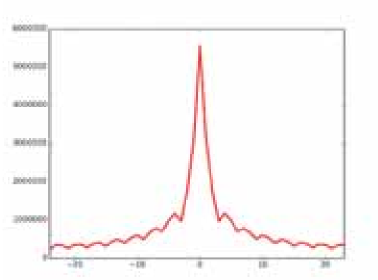
Inside the dataset, some textures images are stationary, while some others appear as a collection of objects (to see figure 5). Looking at the graph of amplitude in the figure 6, the graphics corresponding to *bush* and *wood* are very close, differing in that the maximum amplitudes outside of the zero frequency are more visible in *wood*.



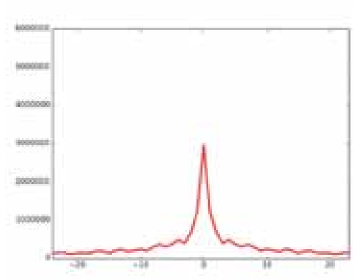
a) Bark 01



b) Bush 08



c) Tree 05



d) Wood 30

Fig. 6– Colour Local Pattern amplitude from *stex* test.

ALOT is an impressive colour image collection of 250 distinct rough textures (some images are shown in the figure 7), acquired by 4 different colour camera (*c=1,2,3,4*). For each image and camera, six illuminations are considered (*I=1,2,3,4,5,8*) and 4 rotations (*r=0°,60°,120°,180°*) [23]. Three image sizes are proposed: full resolution (*1536x1024*) half resolution (*768x536*) and quarter resolution (*384x256*) pixels, all of them of 24 bits. Figure 8 shows that the graphs of amplitude are different for all images.

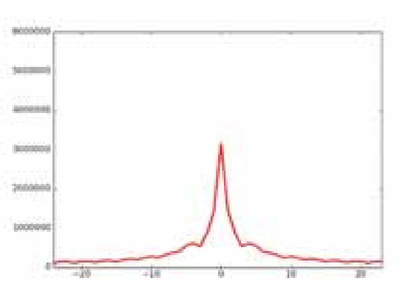
a) Tea

b) Ribbed cotton

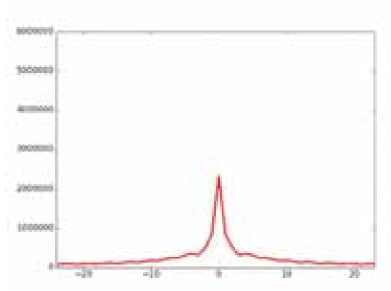
c) Moss

d) Cotton wool

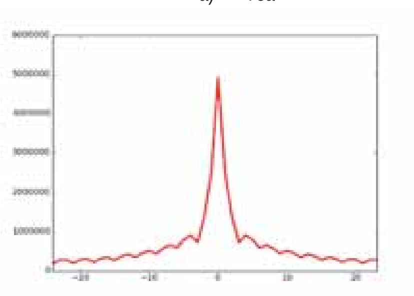
Fig. 7 – Some images of colour texture from *alot* test. The set are the same illumination conditions and 250 images with variations in colour and texture.



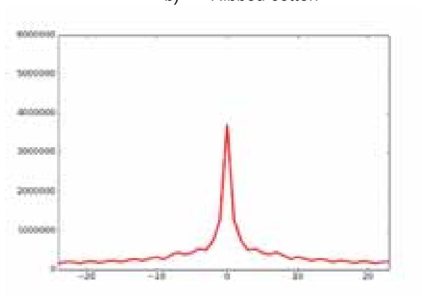
a) Tea



b) Ribbed cotton



c) Moss



d) Cotton wool

Fig. 8– Colour Local Pattern amplitude from *alot* test.

4.2 Distance analysis

Before to address the performance of the CLP feature in texture classification, we analyse the intra and inter-class distance (Euclidean form) in the CLP signature with the goal of evaluate their discrimination capacity. We considered each image I as a class and the centre of class C_{cl} is the average of all CLP signatures that belong to the each sub-image Is of the class I. Then the distance intra-class d_{ic} is:

$$d_{ic}=(1/n)\Sigma\ d\{sig_{cpl\Delta}(Is),C_{cl}(I)\} \quad (7)$$
$$\text{where } C_{cl}=(1/n)\Sigma\ sig_{cpl\Delta}(Is)$$

The inter-class distance d_{inc} is the distance between two centres of class C_{cl}.

$$d_{inc}=d\{\ C_{cl1}(I),\ C_{cl2}(I)\} \quad (8)$$

In tables 1 to 4, the diagonal represents the intra-class distance, and the cells out of diagonal the inter-class distance. According to the table 1 for *OUTEX* database some intra-class values are higher than the values inter-class, as the case of *canvas 1* with *canvas 4* and *canvas 20* with *whool 4*. This means that the classification would be in default for these textures.

	Canvas2	Canvas 4	Canvas 20	Whool 4
Canvas 2	7.26 e6	3.9 e6	11.04 e6	7.28 e6
Canvas 4		1.41 e6	7.06 e6	3.32 e6
Canvas 20			6.74 e6	3.78 e6
Whool 4				4.18 e6

Tab. 1 – Distance Euclidean intra and inter-class for images of outex database.

Table 2 shows the analysis in the selected images from the *VISTEX* database where we can see that in all four cases arises the percentage intra-class is less than the distance between the centres of class. Better performances in classification are expected.

	food	Flower	bark	fabric
Food	10.65e6	12.9e6	27.04 e6	14.6 e6
Flower		5.53 e6	14.16e6	16.69e6
Bark			0.5 e6	30.8 e6
Fabric				7.07 e6

Tab. 2 – Distance Euclidean intra and inter-class for images of vistex database.

Some *STEX* images are analysed in table 3. We found one value very close in the distance between *bush* and *wood* class, than toward the centre of *bush* class. In the other cases, the values between the centres of the classes are smaller than the values out of classes.

	bark	Bush	tree	wood
Bark	2.43e5	29.37e5	11.9 e5	29.74 e5
Bush		2.4 e5	17.95e5	2.94e5
Tree			6.7 e5	18.71 e5
wood				2.68 e5

Tab. 3 – Distance Euclidean intra and inter-class for images of stex database.

In table 4 are the results of the samples of the base *ALOT*, where we have one lower inter-class value between the classes *tea* and *ribbed* as well as *tea* and *moss*.

	tea	Ribbed	Moss	cotton
Tea	1.97e5	0.67e5	1.08 e5	6.13 e5
ribbed		0.78 e5	1.68e5	6.73e5
moss			0.88 e5	5.07 e5
cotton				0.49 e5

Tab. 4 – Distance Euclidean intra and inter-class for images of ALOT database.

4.3 Performance in classification

To compare the impact of the CLP in front of other approaches of LBP for colour images, we select the basic and complete classification scheme proposed by Arvis. Then we compare CLP to a direct approach combining a texture analysis adding its colour average (GLACI) and cross-channel marginal approach (CCMA) as proposed by Maempa [10]. Following this classification scheme, we develop our results on the two colour texture databases *OUTEX* (TC 00013, 68 textures), *VISTEX* (TC0006, 54 textures) as defined by Arvis. However we add *ALOT* (250 textures, 6 illuminates

and 4 cameras) and *STEX* (476 textures) databases that include more complex texture images.
Table 5 shows that CLP obtains a higher rate of a good classification for 3 of the 4 evaluated databases. A gain greater than 10% is obtained in the two databases having a more complex spatio-chromaticity (*STEX* and *ALOT)* [23].

	LBP-GLACI	LBP-CCMA	CLP	Difference
OUTEX	85.7	80.73	82.1	-3.6
VISTEX	97.02	97.45	97.7	0.35
STEX	60.34	71.24	83.9	12.7
ALOT	58.3	70.64	81.3	11.3

Tab. 5 – Good classification rate for grey-level approach with colour information in Local Binary Pattern (GLACI-LBP), Local binary pattern with colour information in cross-channel marginal approaches (LBP-CCMA) and colour local pattern (CLP).

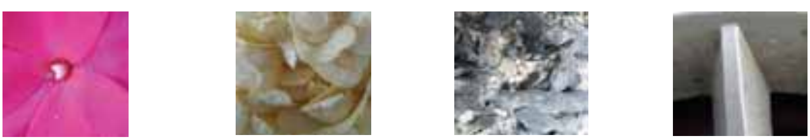
VISTEX database includes some images from the nature, so the inner spatial complexity is more important with multi-scale textures. For such spatial complexity, the local binary pattern approaches are well adapted, with an average gain of 13% in comparison to the *OUTEX* case. For the *OUTEX* database, classical LBP approach using the GLACI construction obtains the better results, in accordance to the fact that the colour complexity of *OUTEX* images is reduced. In this case, there is no necessity to vector processing rather than scalar processing (Gibbs phenomena).

5 Cases with bad classification

Figure 9 shows some images for which the CLP fails in the texture classification task. In the case of *ALOT* images, the colour complexity is reduced as for *OUTEX* case, reducing the interest of the CLP feature for this case of texture discrimination. For the images from *STEX* database, the texture is related to a collection of objects. In this case, the small spatial distance used for the classification (d=3) is not adapted to characterize the texture content.

a) Macaroni (colored) b) Macaroni (penne) c) Chips (natural) d) Shammy

Fig. 9– Images from *ALOT* database that have problems in the classification percentage.



a) Flower 11 b) Food 01 c) Misc. 01 d) Misc. 43

Fig. 10– Images from *STEX* database that have problems in the classification percentage.

6 Conclusion

Kepting the initial idea of the local binary pattern, we proposed a new expression adapted to colour domain. To obtain a feature coherent to the human vision and allowing to compare texture discrimination obtained by machine and human vision, we selected to base our construction on the colour difference processed in a perceptual colour space. The core of the feature is then the frequency representation of the colour differences sequences for a defined spatial neighbourhood.

Obtained signatures of Colour Local Pattern (CLP) are easy to interpret and helps us to identify trends in changes in texture and colour. Static and homogeneous textures present an important magnitude for the null frequency, while the isotropic textures. For more heterogeneous and complex texture, the energy is transferred into the highest frequency in relation to the ratio between the distance parameter and the texture pattern size.

Colour Local Pattern (CLP) approach is more interesting when the spatio-chromatic complexity of images increases. Basic approaches separating texture and colour are more adapted for *OUTEX* images. While the performances are better but close from the classical LBP constructions for colour images in the case of the *VISTEX* database. Finally, for *STEX* and *ALOT* images, where the spatio-chromatic complexity is highest, the gain in performance is close from 10%.

Under another point of view, the CLP expression integrating the texture analysis in a local neighbourhood proposed an efficient implementation of the texton notion proposed by Julesz, without the requirement to a segmentation process. Such consideration allow to imagine new psycho-physical experiments to assess the feature performances in texture discrimination.

Our next trends are to develop a full and vector expression for the Colour Local Pattern (CLP) and consequently to embed the angular variation of the vector difference around the circular neighbourhood in the signature construction.

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3. COLOUR AND LIGHTING

Impact of the choice of different walls' finishing and light scenes

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1. Introduction

In recent years new interior design projects frequently feature walls painted with intense colours, both in residential and tertiary sector applications. Usually the choice of a given walls' colour is made basing on esthetical reasons, or marketing ones in case of tertiary applications. For example it may be decided to paint the walls of a new chain shop with the brand's trademark colour.
However this choice should be also performed according to that of the lighting system since it may have an impact on users' comfort. Indeed a given combination of light sources with a certain spectral power distribution (SPD) with a specific walls' colour may determine an unpleasant environment, visual discomfort or even affect mood and performances. Indeed several studies on the effect of walls' colour on performance, mood, etc. were carried out in the past [1,2,3,4].
The research project reported in this paper aims at analyzing the effects of the combination of different walls' colours and light scenes with different correlated colour temperatures (CCTs) on the spectral distribution of the light that hits users' eyes. Since this study represents the first step of a wider research project only electric light was analyzed, however future studies will also focus on daylight. The CIECAM02 colour appearance model [5] was also applied to investigate if and how the colour attributes of the walls vary when changing the light scene and the results obtained are reported in this paper.
Moreover a previous research by the authors [6] demonstrated that there is a good correlation between hue values calculated with the CIECAM02 colour appearance model and hue values reported by subjects. Therefore the application of this model may also provide indications about people's perception of the environment.
Future tests will be performed to fully investigate users' perception and to further verify the correlation with the CIECAM02 model. It is important to highlight that the CIECAM02 colour appearance model has been criticized by many researchers [7] but so far no modifications or new models were proposed; therefore in this paper the CIECAM02 will be applied since there is no better option.

2. Method

This study was carried out in a test room of the Photometry and Lighting Laboratory of the Department of Industrial Engineering of the University of Naples Federico II (Italy). The spectral reflectance of one of the test room's walls (the one in front of the desk) was changed by applying cardboards on it.
Figure 1 shows the test room's measured plan, the room's window was totally obscured during the study with a panel.

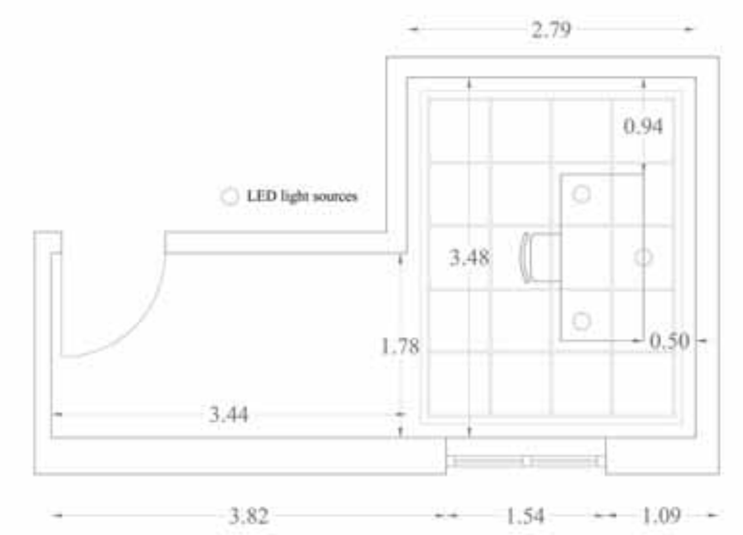


Fig. 1 - Test room measured plan.

The test room is equipped with LED luminaires controlled by a DALI system that allows to change light's intensity, CCT and also to save different light scenes once they are set up. Luminaires' technical specifications and photometry (as provided by the manufacturer) are reported in Figure 2.

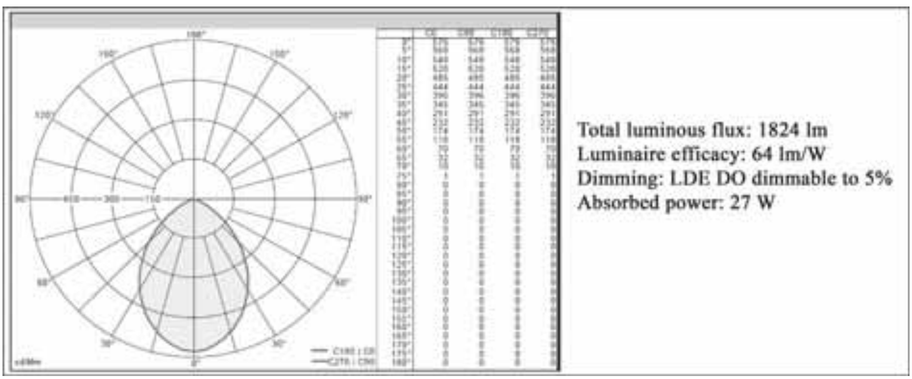


Fig. 2 - Luminaires' technical specifications and photometry.

Four light scenes were set up with different CCTs: 2700 K, 3000 K, 4500 K and 6500 K. All light scenes determine an illuminance value equal to 300 lx on the desk. Table 1 reports for each of them colour rendering index (CRI) values, CCTs and Δuv values all detected with a Konica Minolta CS2000 spectroradiometer.

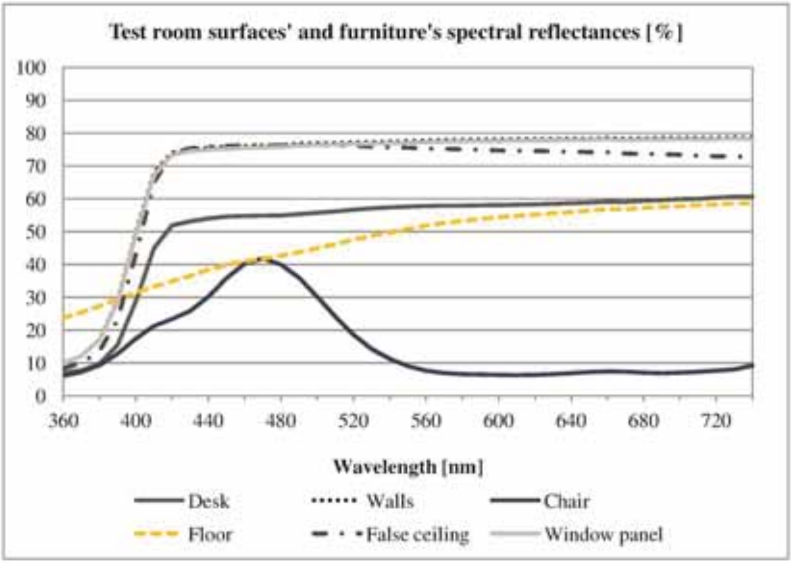
Light scene	Measured CRI	Measured CCT [K]	Δuv
2700 K	90	2626	- 0.0016

3000 K	92	3008	- 0.0035
4500 K	91	4561	- 0.0036
6500 K	90	6555	- 0.0038

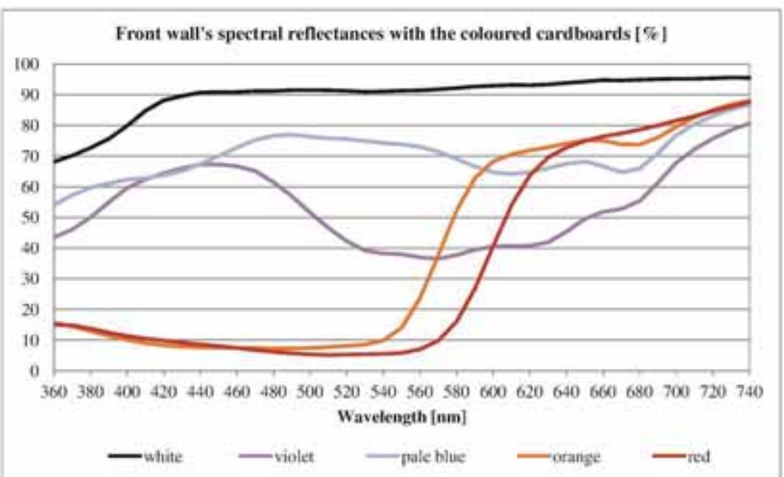
Tab. 1 – Light scenes' characteristics

Figures 3a,b,c report the spectral reflectances, measured with a Konica Minolta CM-2600d spectrophotometer, of the test room's surfaces and furniture and of the front wall with the coloured cardboards on. Light scenes' normalized SPDs are also reported.

a)



b)



c)

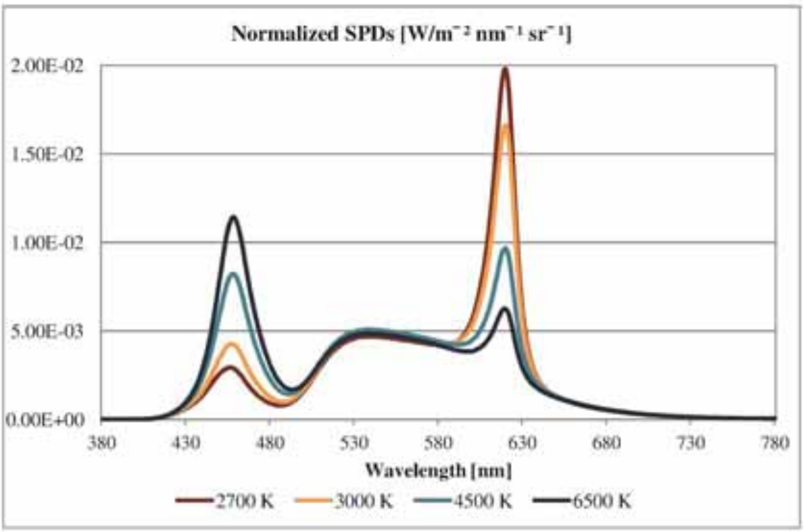


Fig. 3a,b,c - Spectral reflectances of the test room's surfaces and furniture and of the front wall with the coloured cardboards on, light scenes' normalized SPDs.

Figure 4 shows photos of the front wall with the red cardboards on lit by the different light scenes.

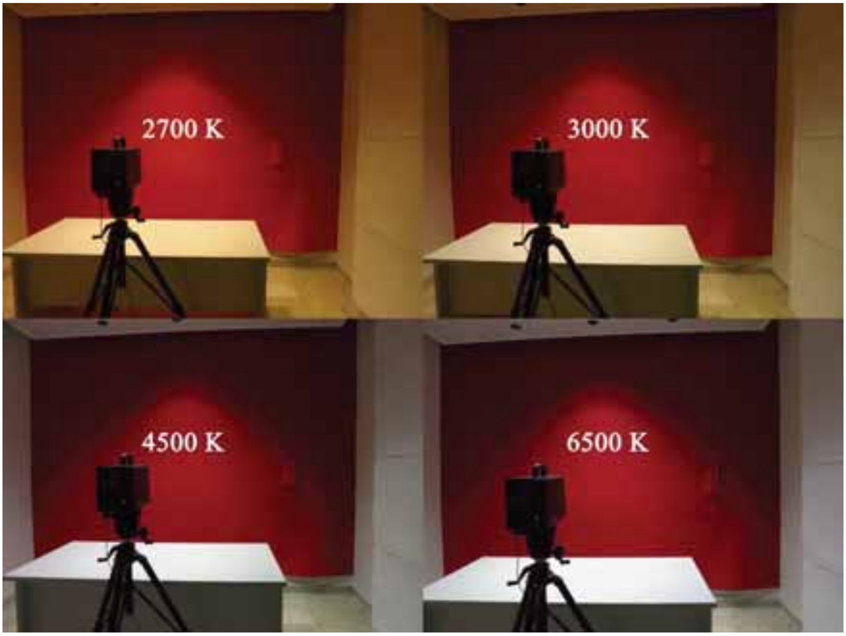


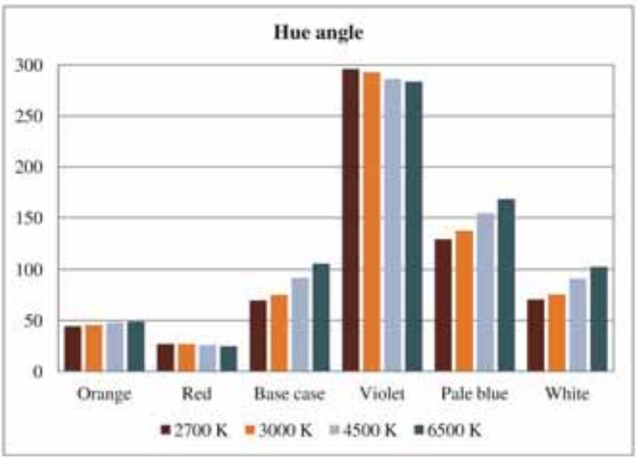
Fig. 4 - Photos of the front wall with the red cardboards on lit by the different light scenes.

To apply the CIECAM02 model the adapting luminance (cd/m^2) was calculated by dividing for π the illuminance detected by placing the spectroradiometer in the same position of the head of a person seated at the desk (at an height of 1.20 m, see Figure 4). The relative luminance of the surround was considered as average. The reference white is an A4 paper sheet placed on the front wall, its tristimulus values were measured with each light scene and coloured cardboard.
Tristimulus values of the coloured cardboards were also detected under each light scene.

3. Results

In the following graphs the results related to the front wall without the coloured cardboards will be referred to as "Base case". Figures 5a,b,c respectively show hue, chroma and lightness values calculated with the CIECAM02 model for each coloured cardboard under all light scenes.

a)



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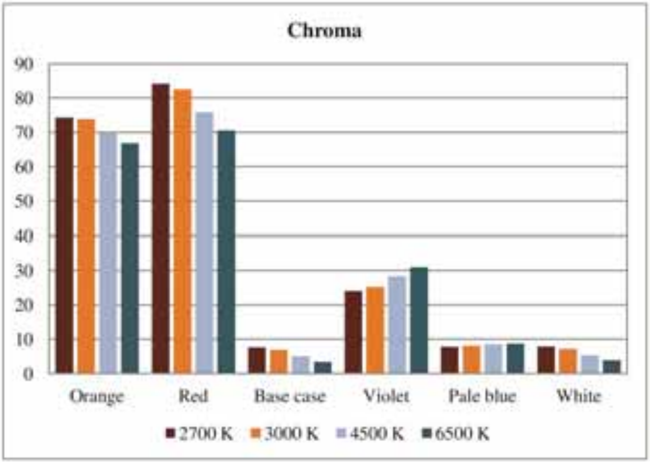

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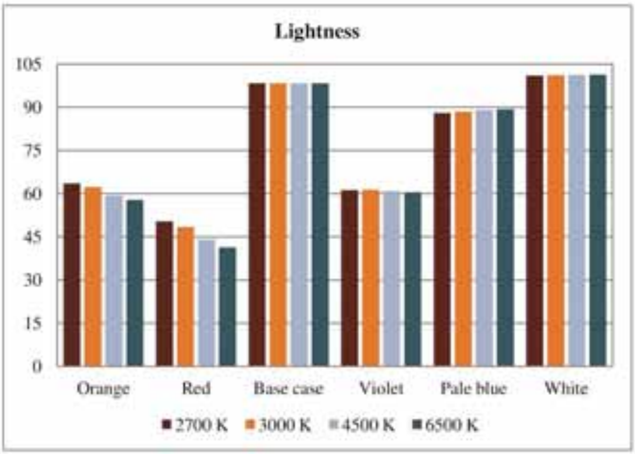

Fig. 5a,b,c - CIECAM02' s hue, chroma and lightness values calculated for each coloured cardboard and light scene.

It is interesting to observe that the greatest variation in hue angle values is found for the base case and with pale blue and white cardboards. Red and orange ones show almost null hue differences when changing the light scene whereas for violet cardboards they increase a little.
On the contrary, referring to chroma values, violet, orange and red cardboards are the ones showing the greatest differences. Orange and red cardboards are also the ones for which the greatest lightness variation was calculated, whereas for the other cardboards there is almost no difference when changing the light scene.
In addition, Table 2 reports colour differences calculated for each front wall's colour using the following equations and taking as reference the values related to the 2700 K light scene.

$\Delta L = L_{2700K} - L_x$ (Eq. 1)
$\Delta H = H_{2700K} - H_x$ (Eq. 2)

$\Delta C = C_{2700K} - C_x$ (Eq. 3)

where the subscript x = 3000 K, 4500 K, 6500 K

$\Delta Eab = (\sqrt{\Delta H^2 + \Delta C^2})$ (Eq. 4)
$\Delta E^*ab = (\sqrt{\Delta H^2 + \Delta C^2 + \Delta L^2})$ (Eq. 5)

		ΔE*ab	ΔEab	ΔC	ΔH	ΔL
Base case	2700 K - 3000 K	5.45	5.45	0.76	-5.40	0.05
	2700 K - 4500 K	22.35	22.35	2.55	-22.20	0.08
	2700 K - 6500 K	36.34	36.34	4.17	-36.10	0.09
Violet cardboards	2700 K - 3000 K	3.33	3.32	-1.20	3.10	-0.12
	2700 K - 4500 K	10.54	10.54	-4.34	9.60	0.31
	2700 K - 6500 K	14.16	14.14	-6.98	12.30	0.72
Pale blue cardboards	2700 K - 3000 K	7.42	7.40	-0.23	-7.40	-0.44
	2700 K - 4500 K	24.43	24.41	-0.68	-24.40	-0.92
	2700 K - 6500 K	38.73	38.71	-0.91	-38.70	-1.23
White cardboards	2700 K - 3000 K	5.05	5.05	0.72	-5.00	-0.04
	2700 K - 4500 K	20.55	20.55	2.50	-20.40	-0.12
	2700 K - 6500 K	32.25	32.24	3.96	-32.00	-0.29
Orange cardboards	2700 K - 3000 K	1.79	1.27	0.42	-1.20	1.26
	2700 K - 4500 K	6.99	5.59	4.44	-3.40	4.20
	2700 K - 6500 K	10.40	8.70	7.45	-4.50	5.69
Red cardboards	2700 K - 3000 K	2.59	1.71	1.71	0.00	1.95
	2700 K - 4500 K	10.49	8.41	8.34	1.10	6.27
	2700 K - 6500 K	16.52	13.81	13.65	2.10	9.07

Tab. 2 – Analysis of chromatic differences

It is interesting to highlight that red and orange cardboards are the only ones for which there is both a great difference in chroma and lightness values. Moreover the greatest colour differences are always those calculated between the 2700 K and 6500 K light scenes. Another interesting result is the great hue variation calculated for the base case. Since it is an almost neutral colour (see Figure 3b) this difference depends on the light scene's variation, whereas in the other cases differences are due to the combination of the cardboards' spectral reflectances and light scenes' characteristics.

4. Discussion and Conclusions

The results reported in this paper highlighted that there are significant variations in the colour attributes of the front wall with the coloured cardboards on when changing the light scene.
To understand if there are also strong differences in people's perception of this environment tests are required. A previous study [6] demonstrated that there is a good correlation between CIECAM02's hue values and hue perceived by people, but to confirm this finding further tests are required.

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Coloured LEDs Lighting For Food Growing

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1. Introduction

Lighting and particularly coloured lighting is a vital factor that contributes to plant growth inducing both photosynthesis, phototropism and photo-morphogenesis. Detailed experimental studies on the photobiology of plants have already shown the importance of creating proper lighting receipts for different species, growth and developmental stages in order to obtain a good plant productivity and nutritional quality formation. LEDs, nowadays, are a good tool for creating the proper lighting receipts composed by different narrow wavelength combined for specific plants. Small dimension, long operating lifetime, great efficiency, digitally controllable features and optically controllable performances are also useful aspects for plants' lighting system development not only for laboratorial research experimentation, for aero-spatial and industrial food production but also in other field such as for educational and therapeutic scopes [1-2-3]. More than this, domestic food farming is currently an increasing trend derived by both the emergent interest in eating healthy, genuine, km-0 and origin controlled food combined with a raising necessity of nature reconciliation through sustainable behaviours and responsible choices [4]. In this regard, an LEDs lighting system for home farming can be a possible solution especially in particular domestic environment lacking natural lighting or good climatic conditions, with limited or absent natural spaces as gardens, terraces and balconies that can be used for farming.

2. Research aim

In this domain, the primary and introductory research scope is defining requirements and features of a lighting system for food growing in domestic environments. If the hypothesis is that LEDs are creating the opportunity for an energy efficient, reliable and qualitative superior system for home gardening, our interest was to investigate and propose a practical and ready to make designed solution considering not only technological problems but also user oriented issues. The research question, at this point of the research, was about the features required from users in a LEDs based lighting system for domestic food farming. This paper is introducing a longer lasting research whose objective is the realization of an easy, economic, efficient, functional and interesting prototype that could be used for experimental research scopes but also for being self-replicated by everyone interested in building his own lighting-for-food-growing system.

3. Research methodology

The requirements of the proposed lighting-for-food-growing system were derived firstly from a scientific literature review about agriculture and food science in order to define the preferred characteristics of lighting for food growing in terms of quantity, spectral power distribution, spatial distribution, direction, temporal distribution. In addition to this, a quantitative - qualitative survey [5] was performed in order to derive further lighting system specifications in terms of end-users' interests and attitudes in using an LEDs based system for home cultivation. More than this, the aim was to gather insights in terms of desired dimensions, domestic location and integration, typology of cultivation, technological simplicity and other features to better define an LEDs lighting system for domestic food cultivation.

4. Lighting requirements for plants

According to the previous works, plants require light throughout their whole life-span from germination to flowering and seed production. Quality, quantity and duration are the most relevant parameters of growing light influencing in different way the plant performance [6]:
• Light quantity (intensity) is the main parameter which affects photosynthesis, a photochemical reaction within the chloroplasts of plant cells in which light energy is used to convert atmospheric CO_2 into carbohydrate.
• Light quality (spectral distribution) refers to the spectral distribution of the radiation: this aspect regards which portion of the light emission is in the blue, green, red or other visible or invisible wavelength regions. For photosynthesis, plants have the maximum response for red and blue light. Light spectral distribution also has an effect on plant shape, development and flowering (photomorphogenesis).
• Light duration (photoperiod) mainly affects flowering.
Plants are very selective in absorbing the proper wavelength according to their requirements. The most important part of electromagnetic spectrum is called PAR (Photosynthetically Active Radiation) which spread from 400 to 700 nm.

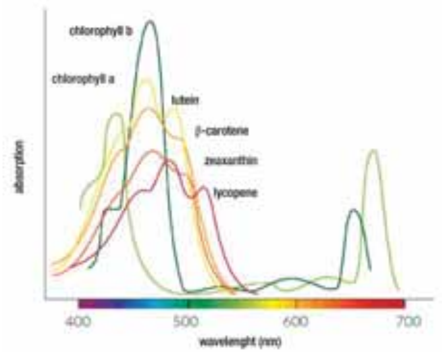


Figure 1 Absorption spectrum of chlorophyll and other photosynthetic pigments.
Adapted by Margherita Giacomozzi from Cibele, Light for Food

The fundamental problem to solve in the lighting engine design is to model different spectral distribution (it means to identify a proper number and driving current of the primary colours) to optimize the plant growth in an efficient way: the main idea is that a controlled and engineered spectral distribution would be much more beneficial for the plants than white light because it would allow to better control the plants' performance such as flowering time, high photosynthetic efficiency, low heat stress etc.
The visible spectrum can be subdivided in several bands and each of them has a defined role in plant's growing and photosynthesis process [7]:

380–400 nm (ultraviolet A/visible light): the process of light absorption by plant pigments (chlorophylls and carotenoids) begins.
400–520 nm (visible light: violet, blue and green bands): peak absorption by chlorophylls occurs in this range and it has a strong influence on vegetative growth and photosynthesis.
520–610 nm (visible light: green, yellow and orange bands): this range is less absorbed by the plant pigments and has less influence on vegetative growth and photosynthesis. [8]
610–720 nm (visible light: red bands): a large amount of absorption occurs at this range, strongly affecting the vegetative growth, photosynthesis, flowering and budding.
720–1000 nm (far-red/infrared): germination and flowering is influenced by this range but little absorption occurs at this band.

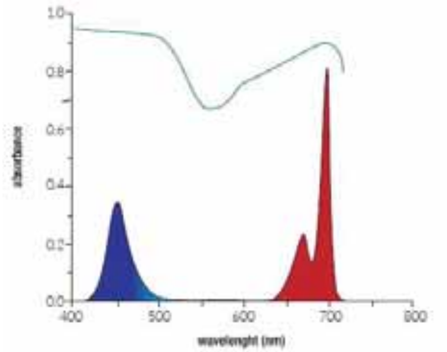


Figure 2 The figure shows the comparison between the spectral power distribution of three different LEDs and the absorbance spectra for the Spinach plant. Adapted by Margherita Giacomozzi from Cibele, Light for Food

The selection of the primary colours (in first approximation we can say that good candidates are red, green-yellow, blue-violet) are important to photosynthesis, but it is also important to consider the relative proportion or “red:blue” - “red:green:blue” ratios. More than this, many studies investigate the best mix of primary light sources in order to match them with the peaks of the absorbance curve of the plants [Figure 2].

5. Users’ requirements for domestic food growing

5.1. Participants

For this study, 63 respondents (38.3% male and 61,7% female) took part in the survey. The average age of participants was 33.45 years old (24-34, 68,3%; 35-47, 31.6%). Half of the participant was living in North Italy (50%) and the other half was spread in Europe (The Netherlands 8.3%, UK 5.0%, Spain 3.3%, Austria 1,7%, Belgium 1.7%, Germany 1.7%, Switzerland 1,7%,), east and far east (China 16.7%, Turkey 3.3%, South Korea 3.3%) and United States of America (3.3%).

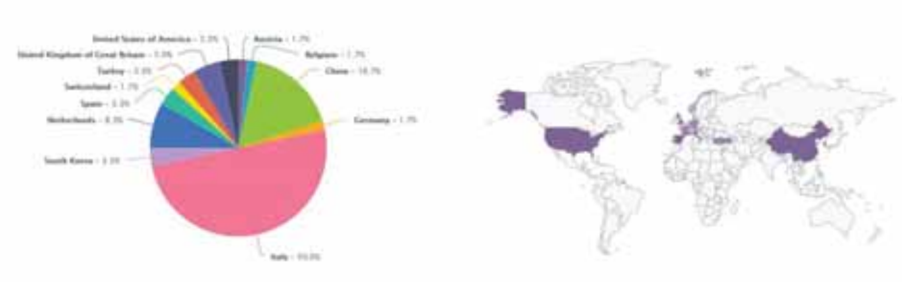


Figure 3 Participants' distribution in the world

The survey was directed to people interested in the growing - farming at home topic: the majority of the participants were architects, designers and engineers (34%) followed by educators, teachers and professors (17%), researcher (10%), psychologists and sociologists (7%) and also forest ranger, chefs, physician, dietitians and employees.

5.1. Users' attitudes toward domestic food farming

The first aim of the research was to understand if people were interested in food growing in their domestic environment and which were the most important reasons for doing so. More than this, the research was also interested in understanding if people were well-inclined and interested in using LEDs based systems for domestic food gardening.

From the survey, a strong majority (71.5% of the participants) affirmed that they were inclined and interested in eating genuine food intending self-grown, km-0, Pesticide-Free (ave. 7.3; std.dev. 2.8 on a 0 - 10 scale). In addition to this, the 65.6% of the participants were positively in favour and willing to cultivate fruits or vegetables in their home with indoor growing systems (ave. 6.2; std.dev. 2.5 on a 0 - 10 scale). Despite of this, when people were asked about their skills and knowledge in gardening and cultivating, the 52.5% of them showed not to be green-fingered and good in food growing (ave. 4.3; std.dev. 2.7 on a 0 - 10 scale). From this preliminary results, some insights could be derived indicating the latent need of providing systems for gardening and food growing that are also helping and supporting users with information, on-time knowledge and feedback for better farming outcomes.

When people were asked if they would be interested in using an LEDs based system for cultivating indoor the results were more spread: the 48,2% of them were positively interested, the 21.4% were showing a neutral attitude and the 30.4% were not interested (ave. 5.8; std.dev. 2.6 on a 0 - 10 scale). This preliminary outcome was possibly indicating that a good number of participants would prefer using natural lighting for its home-grown farming system. Exploring the good reasons why people would consider the opportunity to use an LEDs based system for cultivating indoor, we found that primarily there was the lack of spaces with nature such as garden and balconies (41.3%), and consequently the lack of natural lighting and bad weather conditions particularly in winter. In addition to this, people affirmed again the strong intention and real interest in growing the food for their own consumption (39,7%), also appreciating the opportunity of cultivating (and so eating) some species off season (33.3%) and considering the interesting possibility of

experimenting and learning how to grow their food (25.4%). Other consideration regarded the educative and therapeutic purpose of horticulture at home (36.5%) that helps in stimulating children, adults and elderly people in their physical (exercise, sensory, stress release) psychological (accomplishment, confidence, biophilia hypothesis, connection with nature) intellectual (observation, experimenting, creativity, curiosity) and social skills (community, sharing).
Finally, LEDs were recognized as a more efficient technology for indoor growing compared to traditional lighting systems not only in terms of lower energy consumption but also in terms of the lighting quality provided that responds more precisely to plants' needs, thus defining a more productive growing system.

6. Requirements for an LEDs lighting system for domestic food growing

From the scientific literature review and the survey, some requirements for domestic food farming with an LEDs lighting system were defined. In particular, the research investigated features like dimensions, location and integration of the system in the domestic environment. In addition to this, the typologies of cultivation were explored and related to the proper lighting in terms of quantity, quality and duration for producing a congruous amount of species (not intensive industrial production) with particular interest in the efficiency of the LED based lighting system combined with good flavours, aromas and nutrients of the food. The exploration focused also on the homely feeling of the system considering the aesthetics, pleasantness, interest and domestic suitability. More than this, considering the not professional users, the investigation focused also on the perceived functionality and the overall simplicity of the system (installation, use, cleaning/maintenance, control and management).

6.1 Domestic integration: dimension and location

The space required and considered available and useful for a domestic farming system was preferentially (49.1%) a thin, vertical volume with approximate dimensions of 0.3 x 0.3 x 1.6 m followed by the preference for a cubic compact volume (31.6%) of about 0.8 x 0.8 x 0.8 m.

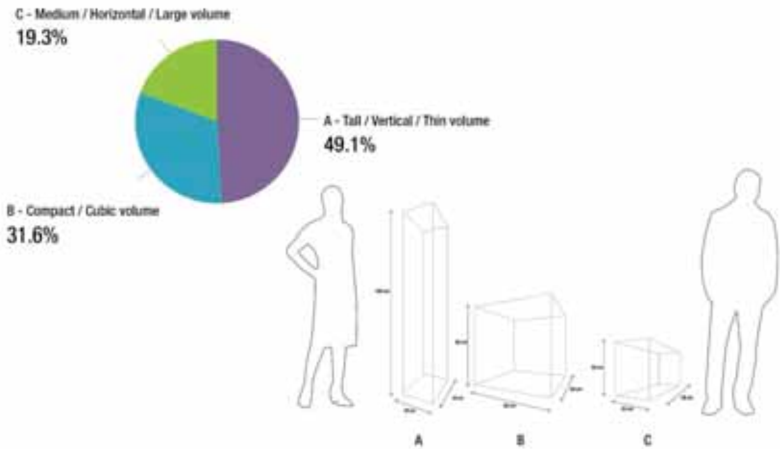


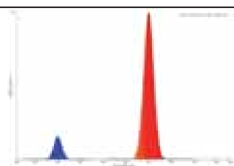
Figure 4 Domestic integration: dimensions preference

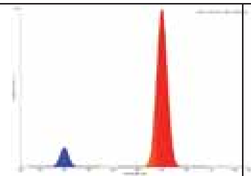
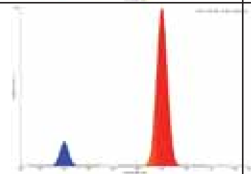
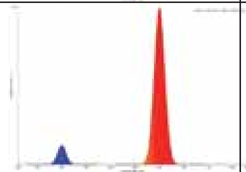
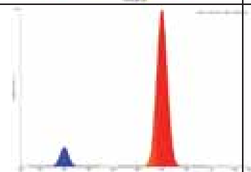
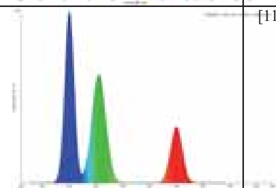
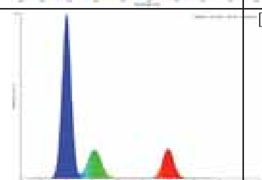
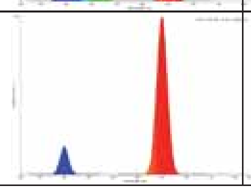
This response seemed to indicate both the need of a consistent and appropriate capacity for cultivating a proper amount of food by discarding the smaller proposal, and, in the meantime, having also a compatible and harmonious shape in relation to other domestic furniture, optimizing and fitting it into the limited domestic space available. In relation to this, the majority of the participants indicated that they would place the system on the kitchen countertop (45%) or exploit the pavement in any other available space of the house (38.3%), especially in the living/drawing room and in the dining room. This is particularly true in condense high-rise apartment buildings meanwhile in other situations, with single apartment as villas and wider spaces, people suggested the use of a specific room such as a winter garden (20%), an old annex of the house or the basement / garage.

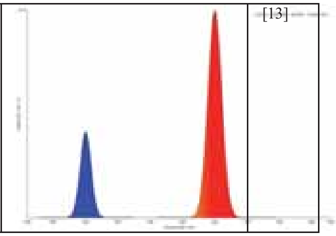
6.2 Typology of cultivation and lighting needs

The LEDs lighting system for domestic gardening and farming resulted especially interesting for the cultivating vegetables (73.3%) such as Spinach, Swiss chard, Artichoke, Zucchini, Cabbage, Eggplant, Lettuce, tomatoes, cauliflower, fennel, celery, cardi, dandelion, broccoli head, endive, peppers, cucumbers, chicory, broccoli, turnip, pumpkin, leek, spices and aromatic / medicinal plants (61.7%) such as cumin, marjoram, thyme, chives, oregano, basil, mint, parsley, rosemary, sage and also small-medium fruit plants (51.7%) such as strawberries, blueberries, raspberries, blackberries, currants. Less interest was shown in cultivating legumes (beans, lentils, peas, green beans, broad beans, soybeans, chickpeas, lupins), exotic fruit and vegetables and tropical flowers. The lighting needs were derived from the scientific literature review according to the most selected cultivation and the lighting receipts (lighting quantity, quality and duration) were identified in order to be suitable and adaptable to the majority of plants my mixing the wavelength in an appropriate way and trying to limit the amount of different LEDs channels (primary colours) that could be a problem in terms of the overall costs of the system. In the following table [Table 1], a summary of the typology of cultivation and related lighting needs / receipts was provided with examples.

Table 1 typology of cultivaltion and related lighting receipts (quality, quantity, duration)

Type	**Nomenclature**	**LED light source Dominant Wavelength (nm)(*)**	**Ratio Red:Blue %Red: %Green: %Blue**	**PAR (400-700 nm) μmol*m^{-2}*s^{-1}**	**Photoperiod (light/dark) Hours**	**Spectral power distribution**	**Reference**
Lettuce	Lactuca sativa	450,650	8:1	200	18/6		[9]

	-	450,650	10:1	250	18/6		[10]
Radish	Raphanus sativus	450,650	8:1	200	18/6		[9]
	-	450,650	10:1	250	18/6		[10]
Spinach	-	450,650	10:1	250	16/8		[10]
Cucumber	Moskovskii Teplichnyi	450,505,650	17.5%:40:42.5%	424	14/10		[11]
Tomato	Starfire	450,505,650	15%:17.5%:67.5%	409	16/8		[11]
Strawberry	Fragaria Ananassa Duch	450,650	7:1	200	16/8		[12]

	Fragaria vesca	450,650	3:1	100	16/8		[13]

For simplicity and for cost reduction, for each spectral band only one value of the peak position has been considered for the development of the experimental lighting engine.

Table 2 Primary LED colour for horticulture light source

LED Colour	Dominant Wavelength (nm)	Spectral bandwidth at 50% $I_{rel\ max}$ (nm)
RED	650	25
GREEN	505	30
BLUE	450	20

6.3 Functionality + Simplicity + Domesticity

People were confronted with three different proposed solutions in order to investigate their general preference in relation to features such as simplicity (use, installation, cleaning/maintenance) domesticity (pleasantness and interest), functionality (flexibility and modularity).

In the first proposed solution [Figure 5], the intelligence and lighting performance are hidden into a lighting bulb designed for domestic agriculture. It can be used with traditional domestic pre-owned lighting fixtures placed over the plants to grow.

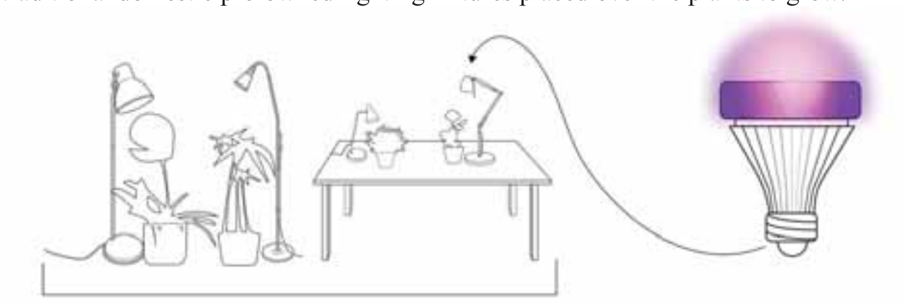


Figure 5 The first proposed solution: traditional lighting fixture with a horticultural retrofit lighting bulb

Compared to the other proposals, this one was evaluated as the most simple in terms of maintenance (46.7%) and generally simple in understanding and using it. On the other hand, it was considered the least functional (16.7%) in terms of "low effectiveness in food production" and very low system upgradability (13.6%). In addition to this, it was considered the least appealing in terms of aesthetics (8.9%) and compatibility with the domestic environment (19.6%) because *"it might take a lot of space"*. Conversely, the possibility of *"up-cycling the old lighting fixtures"* was considered a positive feature.

In the second proposed solution [Figure 6], the intelligence and lighting performance are hidden into a designed lighting fixture which is both functional and decorative. It can be used for home-grown farming but also, when the user is not interested in using it for cultivation (namely in spring/summer) for creating particular lighting atmospheres in the domestic environment.

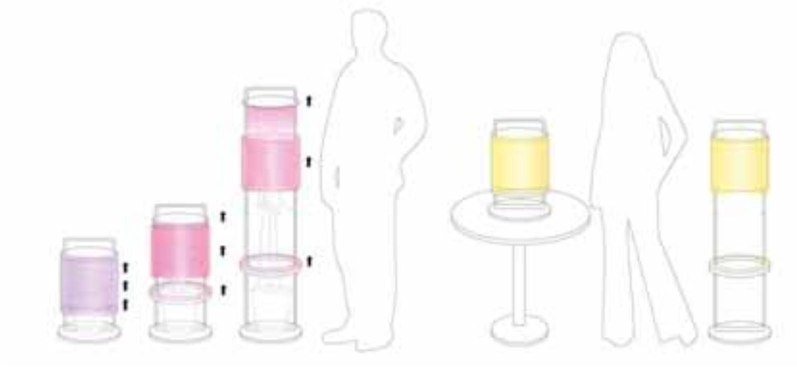


Figure 6 The second proposed solution: a double functional horticultural /decorative lighting system

Compared to the other ones, this solution was evaluated positively in terms of compatibility with the domestic environment (39.1%) and the best solution in terms of aesthetics (55.6%) particularly for its *"elegance"*. In terms of functionality it was considered flexible (40%) but not particularly practical (23.8%) for an effective food production.

In the third proposed solution [Figure 7], the intelligence and lighting performances are integrated in a lighting engine that can be placed into a domestic cabin system by hacking and re-adapting it. This can be placed in storage rooms hidden from the domestic environment, or in dining / living rooms integrated with the functions of a library. It can be combined in a modular and repeatable way depending on cultivation.

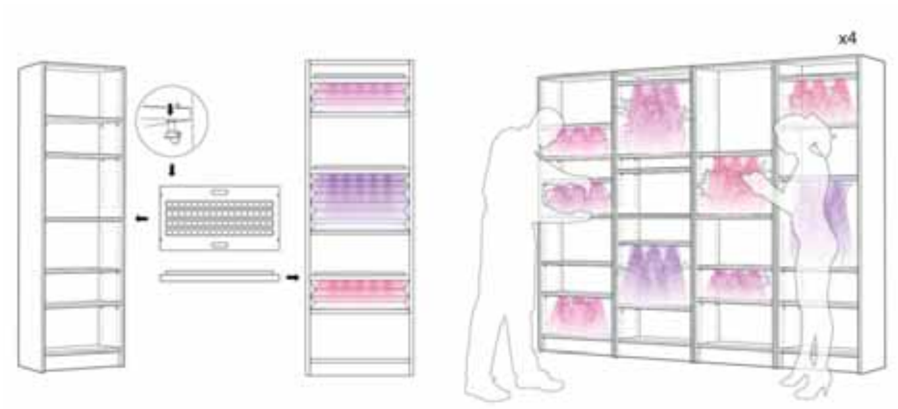


Figure 7 The third proposed solution: modular scalable furniture hacked with an horticultural lighting engine

Compared to the previous proposals, this solution was evaluated as the most interesting and highly appreciated both in terms of functionality (59.5%) for cultivating and farming a reasonable amount of food in an adaptable, modular and upgradable way (52.3%) but also highly compatible with the domestic environment (41.3%). It has been considered simple, easy and practical *"especially for growing different pots and different plants with different needs of light"*.

6.4 LEDs lighting for domestic food growing controls

In relation to the control and management of the LEDs lighting for food-growing system, the segment of people participating to this survey preferred the application (app) to be downloaded and used on the personal mobile phone (customizable depending on user expertise) and the physical controls (such as switches, control knobs, sliders, timer located on the system over the possibility of using a software to be downloaded on a personal computer (customizable depending on user expertise). These insights could suggest that, for this group of users, currently the traditional physical controls and the application on the smartphone have the same perceived simplicity both in use and maintenance. In both of the cases the controls should be flexible in terms of information provided, adaptable to different cultivation and also self-explanatory. In addition to this, the interface should be useful not only for controlling the lighting system but also, through the use of sensors, for informing and sending feedback to the “not so green fingered users” and for increasing their skills and knowledge in gardening and cultivating.

7. Conclusions

This paper focused on setting the requirements, envisioning some insights about domestic food farming with LEDs based lighting system and defining some guidelines for the development of a product/ prototype based both on the scientific review and on users’ feedbacks, assessment and elicited observations. Further steps of the research would imply the development of a fully working prototype with the previously defined features that would be provided to several users for testing it in a real environment and also that would be released as an open-source project [14] to be built and hacked by who is interested in domestic food farming with LEDs.

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Versatility: Lighting Design and Display Systems

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1. Introduction

The lighting in the museums must enhance the exhibited pieces' qualities, guaranteeing its homogeneity to annul the variation of the day, of the night and of their transitions. It can also be combined with the emblematic expression of coloured lights as a symbolic representation.

The colour of light is of crucial importance in the combination of these aspects and in the way we appreciate the colours of the exhibits. This becomes even more relevant when facing the lighting of paintings.

It is also important to consider the status in which it is intended to present the object - appreciation of their aesthetic dimension, expression or details, leading to the choice between different types of lights.

The lighting versatility can also multiply the potential of objects to expose that, in certain conditions, may be valued under different types of lights. Their combination allows mixing the shades of light, to articulate the cold light with warmer tones of other light sources. It is a strategy to reduce costs that can be translated into sensitive tonal nuances of great quality in construction environments.

In view of the new paradigm of energy savings and sustainability, all the Design should be guided by sustainable concerns [1].

So they should follow the principles of Sustainable Design using the thought of life cycle throughout the process; respecting and responding to the unique characteristics of each site; conceptualising to reduce the use of natural resources and minimizing environmental impact; conserving energy; using environmentally responsible materials; conserving water; providing a healthy environment; reducing or eliminating waste.

Therefore, the principles of Sustainable Design should be followed having in mind the life cycle thinking throughout the whole process; respecting and responding to the unique characteristics of each site; conceptualising in order to reduce the use of natural resources and minimizing environmental impact; conserving energy; using environmental responsible materials; conserving water; providing a healthy environment; reducing or eliminating waste.

A sustainable life generates a continuous cycle, with the demolished materials to be reused or recycled to make new products, avoiding waste and having a minimal impact on the environment [2].

Design must be planned with versatility and in a way that, in case there is waste, you can apply it in future projects.

As case studies the Museum of the Presidency of the Republic and the Museum of Banking were selected, both located in Lisbon, Portugal.

2. The Museum of the Presidency of the Republic, Portugal

The Museum of the Presidency of the Republic, designed by the architects Rui Barreiros Duarte and Ana Paula Pinheiro, is the outcome of competitions that took

place in 1997 (architectural rehabilitation), in 2002 (accomplishment of the museum program) and in 2014 (celebration of its 10th anniversary).
The Museum was conceived as a box coated in white marble that could host the most diverse exhibitions [3].
It was designed in order to free the space, eliminating loose display cases (Fig. 1).
These are inserted on the walls, with all the electrical infrastructures hidden behind. Each panel has a power supply with ventilation and independent control. The lighting of the display cases is performed by fibre-optic that allows the viewer to see only the light and not the spotlights.
As this is the Museum of the Presidency of the Republic, the central space is lit by LED lights, with the red and green colours of the Portuguese flag, creating a chromatic immanence background for the display cases (Fig. 2, Fig. 3, Fig. 4).


Fig. 1 - Museum of the Presidency of the Republic. Ground floor. Photography: FG+SG.

Fig. 2 - Museum of the Presidency of the Republic. Portrait Gallery. First Floor. Photography: FG+SG.

Fig. 3 - Museum of the Presidency of the Republic. Display cases. Photography: FG+SG.

2.1. Rehabilitation of the Museum (reduce, reuse, recycle, renew)

In 2014, for its 10th anniversary celebration, a new rehabilitation of the Museum was made. Its Design took into consideration its economical and material sustainability choosing the principle of reduce, reuse, recycle, and renew.

To reduce the quantity of used materials; to reuse existent materials, spotlights and display cases with new functions and adaptations promoting the economic sustainability of the exhibition; to recycle materials and systems; to renew the use of materials selecting them from renewable resources [4].

Fig. 4 - Museum of the Presidency of the Republic. Central space lit with the colours of the Portuguese flag. Photography: FG+SG.

2.2. Ephemeral exterior intervention

In the outdoor patio an ephemeral exterior intervention was created - three geometrical trees with interior lighting. The colours chosen for the trees were, once again, the colours of the Portuguese flag. Therefore, according to the events or day time, different effects can be created, turning the trees red (Fig. 5), green, white, or even with three colours.

This installation allows an outside covered route for those going to the Museum. Also, it works as an urban signal, enabling and encouraging the creation of several outdoor events.

Fig. 5 - Museum of the Presidency of the Republic - the three geometrical trees in the outdoor patio. Photography: FG+SG.

3. The Museum of Banking, Lisbon

The Museum of Banking in Lisbon, Portugal, designed by the architects Ana Paula Pinheiro and Rui Barreiros Duarte, corresponds to the rehabilitation of a space that already had air conditioning, electric and sound infrastructures. The intervention made the most out of the existing elements of the space. The ceiling configuration was kept unaltered but the lighting rails were recovered and relocated. The coating of the existing pavement was maintained, having only performed its cleaning and maintenance.

The area of the windows was not intervened at and ensures the natural lighting of the space, which will pass through the movable glass display cases (Fig. 6).
The walls were covered with removable panels, related to the display cases, freeing the existing walls coated with stone that are visible near the windows and the ceiling (Fig. 6, Fig. 7).
In addition, a platform that defines the exhibition spaces and individualizes the routes was created.
The free spaces make it possible to host a significant number of visitors, without making the system go into entropy.
The existing pillars were encompassed in the display cases so that their presence was annulled (Fig. 8).
Display cases of significant dimensions were created, where one could expose different types of pieces and two plasterboard panels that create conditions for the exhibition of paintings and other objects that can be hung.

Fig. 6 - Museum of Banking. Rendering with Exhibition. RBD.APP – Architects.

3.1. Lighting Design

Just like in the Museum of the Presidency of the Republic, fibre-optic lighting was used to light the display cases. The light of the paintings will be made through LED spotlights, which will be placed in the existent lighting rails in the ceiling. These also act as a complement of light to a display case that might have pieces that need extra lighting.

The combination of ambient lighting in LED does not interfere with fibre-optic lighting of the various display cases. These are available for displaying various pieces, either by changing, or due to the existence of temporary and thematic exhibitions (Fig. 9, Fig. 10).

Fig. 7 - Museum of Banking. Photography: Telmo Miller.


Fig. 8 - Museum of Banking. Photography: Telmo Miller.

Fig. 9 - Museum of Banking. Photography: Telmo Miller.

Fig. 10 - Museum of Banking. Photography: Telmo Miller.

The fact that some of the display cases are movable, allows the versatility of the space. It makes it easier to the exchange the pieces and the sequence of the exhibition itself. This versatility is further amplified by the fact that each display case will incorporate its own source of fibre-optic, which makes it self-sufficient.

The way of presenting the objects under the light creates conditions for their appreciation. Thus, one can expose parts that despite not having great artistic importance, are important when read in a group which refers to a particular theme, telling a story of technologic development, or an activity in its own time.
There are objects that lead us to an artistic dimension, technical or in memory, being important how they are highlighted.
The lighting creates the surrounding conditions of a visual discourse that highlights relevant aspects of the narrative. Such as sound, light exists without imposing itself.

3.2. Energy Conservation

Throughout the Project the principles of Sustainable Design were followed [5]. There was a concern to conserve energy, both by minimizing the energy used during the construction process, as well as specifying energy efficient systems, fixtures, appliances and equipment, and maximizing natural lighting.
The lighting creates the conditions for the spatial qualities to be revealed in sensory terms - environmental and dimensional - taking advantage of the intensity, location and colour, in the links established between objects, in modelling the space. The set quality is given through the relations among the pieces located underneath the light. Its effect creates a consciousness that arises intensities, taking advantage of the light as a construction element.
It is the relation systems under the light that enhance the minimalist dimension of the intervention creating availability for the reception of the pieces and visitors.

4. Conclusions

It is important to have in mind the material's specification, in order to consider the entire life cycle. In interior design this aspect is even more important due to the fact that it works essentially with finishing materials.
The versatility of the spaces, of the ways and means of lighting the inside and the outside of the display cases - which act as containers - are essential factors when exposing different pieces and to mount various types of exhibitions.
One can therefore conclude that an exhibition can be enhanced or annulled due to good or bad lighting choice and placement. It is the lighting that influences the whole exhibition course, guiding the observer through the space and creating the perfect message and atmosphere.

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4. COLOUR AND PHYSIOLOGY. COLOUR AND PSYCHOLOGY

Computer tests for diagnosis of color vision deficiencies

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The aim of this work is presenting the implementation of four computer programs useful for the diagnosis of color vision deficiencies and anomalies of a human observer. However, the true diagnosis must be left to the ophthalmologist which uses the standard protocols of ophthalmology.
Physiology of the visual system gets into any investigation of the color vision deficiencies and anomalies, and thus the ground state of this physiology needs to be recalled. Color vision is based on three kinds of photosensitive cones, which are activated by the number of absorbed photons. A cone signal processing occurs in the neural network starting from the cones with no loss of information producing chromatic and luminous sensation.
The observers with different spectral sensitivities to those of the standard observer are named *anomalous trichromats*; the observers with only two kinds of cones are *dichromats* (or *daltonics*); the observers with only one kind of cones are *monochromats* and have no chromatic discrimination.

- Dichromats are subdivided into three kinds:
  1. *protanopes*, lacking in L cones;
  2. *deuteranopes*, lacking in M cones;
  3. *tritanopes*, lacking in S cones.
- Analogously, three kinds of *anomali*:
  1. *protanomali*, if the anomaly regards the L cones;
  2. *deuteranomali*, if the anomaly regards the M cones;
  3. *tritanomali*, if the anomaly regards the S cones.

The causes of almost all the anomalies have a molecular genetic explanation,
The severity of the anomaly depends on the size of the shift of the photopigment absorbance.
The vision of dichromats and anomalous trichromats allows a normal life and visual deficiencies are often shown only by specific tests.
Since dichromats have only two kinds of cones, their color sensations are represented in a two dimensional space. The comparison of this space with respect to a trichromat one shows that sets of equal colors for one kind of dichromat correspond to sets of different colors for the trichromats. The points representing the chromaticities of these colors belong to straight lines on the chromaticity diagram, named *confusion lines*. Any kind of dichromats has its own confusion lines. The confusion lines of any kind of dichromat have a common point named *confusion point*. Particular monochromatic radiations appear as *achromatic* to the dichromats.
Luminance, which is a photometric quantity related to the luminosity sensation, depends on the activations of the M and L cones. Dichromats with one kind of these cones lacking or anomalous trichromats have different luminous sensations to those of the standard observer. This phenomenon is small and not discriminating.

Table 2.2.1 Human population and color vision anomalies and deficiencies.

Observers		♂ %	♀ %	$V(\lambda)max$ [nm]	λ [nm] *neutrality*	***Rods and cones***
Normal trichromat		~92	~99.5	555		Three kinds of cones (*L*, *M*, *S*) with normal spectral sensitivities
Anomalus trichromat	Protanomalus	1.0	0.02	540		Three kinds of cones with spectral sensitivities with maximum shifted with respect the normal.
	Deuteranomalus	4.9	0.38	560		
Dichromat	Protanope	1.0	0.02	540	494	Without L cones
	Deuteranope	1.1	0.01	560	499	Without M cones
	Tritanope	0.002	0.001	555	570, 400	Without S cones
S cones monochromat				~440		With only S cones
Rods monochromat		0.003	0.002	507		With only rods

The tests presented in this software shows the differences between the luminous efficiency function of the user and of the standard photopic observer CIE 1924, which is the same of the standard colorimetric observer CIE 1931.
The set of tests begins with considering 15 color patches, equiluminant for the CIE 1931 standard colorimetric observer and for the CIE 1924 standard photometric observer, and is organized in four steps:

1. *Luminance matching of heterochromatic colors*

The matching of the luminances of the 15 samples perceived by the individual user, obtained by changing the luminances until the minimum distinction of the borders between samples and surround (*minimum distinct border technique*) are detected. Once the etherochromatic matching is obtained for all the colors, the comparison between the user and the standard observer is made by clicking on the corresponding toolbox. The differences between the standard observer and individual observers are small: tritanopes have normal photometric vision and the others have the contribution to the luminance given by M or L cones, whose spectral differences are small. Normal observers, with the crystalline lenses of the eyes yellowish and darkened by age, have filtering of the light before the light crosses the retina. This filtering could produce a different luminous sensation with respect to a young observer, partially minimized by an adaptation phenomenon. A limitation of this test is due to number of 8 bits used to specify the colors, according the sRGB standard. This test has a low discrimination power and the diagnosis is approximate.

2. *Ordering of heterochromatic colors*

This test, recalling the Farnsworth test, regards the chromatic ordering of 13 of the 15 color samples, previously matched in luminance. The ordering starts from a fixed sample and follows choosing the closest perceived color sample among the not yet chosen samples until the whole sample set is used-up. Once the color ordering is obtained for all the colors, the comparison between the user and the standard observer is made by clicking on the corresponding toolbox. This test is significant.

3. *Achromatic spectral stimuli detection*

The third test regards the detection of perceived achromatic colors on the color circle. Dichromats have two achromatic points on the color circle, of which one is better detectable. The colors of the color wheel are shown on a strip at the top of the screen, and one of these colors is presented in a strip and in a grey square at the center of the screen. The user changes the color in the circle searching for an achromatic color, if it exists for him. The user has to record the detected achromatic color by a click on the appropriate key. The dichromats have two achromatic colors on the color circle. Generally one is better detected than the other. Once made the detection by clicking on the key “results” appear a windows where the wavelengths associated to the achromatic points are given. The protanopes have the achromatic point around 490-500 nm, the deuteranopes around 500-505 nm and tritanopes around 565-575. For the protanopes and deuteranopes the second achromatic points is the magenta hue region. Since the color presented by monitor are not monochromatic but obtained by broad band lights activating also S cones, the achromaticity is perceived with some uncertainty, mainly in the magenta hues. Anyway, the method is well selective for dichromats.

4. *red-green-yellow matching*

The fourth test regards the matching of a red-green color mixture with a yellow color, and recalls the use of the Nagel anomaloscope and the Rayleigh match equation. In this anomaloscope the light sources are red, monochromatic with wavelength λ_R= 670-671 nm, green, λ_G= 546-549 nm and yellow, λ_Y= 589 nm, and are represented by color stimuli with chromaticities lying on the confusion line common the protanopes and deuteranopes.
Consider a yellow radiance $L_{Y,\lambda}$ obtained as sum of the radiances $L_{R,\lambda}$ and $L_{G,\lambda}$, of the red and green lights of the monitor, respectively and suppose as approximation that these radiances do not activate the S-cones. The activation of the L- and M-cones produced by these lights separated are:

$$
\begin{aligned}
L_R &= \int_{380}^{780} L_{R,\lambda}\bar{l}(\lambda)\mathrm{d}\lambda, \quad L_G = \int_{380}^{780} L_{G,\lambda}\bar{l}(\lambda)\mathrm{d}\lambda \\
M_R &= \int_{380}^{780} L_{R,\lambda}\bar{m}(\lambda)\mathrm{d}\lambda, \quad M_G = \int_{380}^{780} L_{G,\lambda}\bar{m}(\lambda)\mathrm{d}\lambda
\end{aligned}
\qquad (1)
$$

and together:

$$L_{\mathrm{Y}} = \int_{380}^{780} \left(L_{\mathrm{R},\lambda} + L_{\mathrm{G},\lambda}\right)\bar{l}(\lambda)\mathrm{d}\lambda = L_{\mathrm{R}} + L_{\mathrm{G}}$$

$$M_{\mathrm{Y}} = \int_{380}^{780} \left(L_{\mathrm{R},\lambda} + L_{\mathrm{G},\lambda}\right)\bar{m}(\lambda)\mathrm{d}\lambda = M_{\mathrm{R}} + M_{\mathrm{G}} \tag{2}$$

A modulation of the radiance of the red light by a factor R and that of the green light by G, with sum leaving unchanged the activations L_{Y} and M_{Y} is represented by the equations

$$\begin{cases} L_{\mathrm{R}} + L_{\mathrm{G}} = L_{\mathrm{Y}} \\ M_{\mathrm{R}} + M_{\mathrm{G}} = M_{\mathrm{Y}} \end{cases} \quad \rightarrow \quad \begin{matrix} RL_{\mathrm{R}} + GL_{\mathrm{G}} = L_{\mathrm{Y}} \\ RM_{\mathrm{R}} + GM_{\mathrm{G}} = M_{\mathrm{Y}} \end{matrix} \tag{3}$$

This set of two equation with two parameters, R and G, considered as unknowns, has only one solution, that regards the trichromats and is $R = G = 1$. For the protanopes and deuteranopes the two equations of the set have to be considered separately and follow that R and G are in linear relation and the parameters of these equations are proper of the protanopes and deuteranopes, respectively:

$$\begin{matrix} \text{deuteranopes} & RL_{\mathrm{R}} + GL_{\mathrm{G}} = L_{\mathrm{Y}} & \rightarrow & R + G\dfrac{L_{\mathrm{G}}}{L_{\mathrm{R}}} - \left(1 + \dfrac{L_{\mathrm{G}}}{L_{\mathrm{R}}}\right) = 0 \\ \text{protanopes} & RM_{\mathrm{R}} + GM_{\mathrm{G}} = M_{\mathrm{Y}} & \rightarrow & R + G\dfrac{M_{\mathrm{G}}}{M_{\mathrm{R}}} - \left(1 + \dfrac{M_{\mathrm{G}}}{M_{\mathrm{R}}}\right) = 0 \end{matrix} \tag{4}$$

The test proposed by the software consists in the search for a color match different from $R = G = 1$. If such a match exists for the observer, he or she is not a trichromat and the parameters of the fitting line characterise the kind of dichromatism.

This test is approximate because the cromaticities of the red and green colors of the monitor do not belong to a confusion line common to protanopes and deuteranpes, although not too distant. For correctness, the observer should see through an optical high-pass filter with cut-off at the 550 nm wavelength to be sure of the S-cone exclusion.

The software consider the color stimuli in the RGB laboratory reference frame, where the tristimulus value are represented by 8 bits numbers. In this case the two stimuli displayed in the two halves of the bipartite field are (R, G, 0) and (Y, Y, 0), where $0 \leq R, G, Y \leq 255$. These stimuli specified in the fundamental reference frame become:

$$\begin{pmatrix} L \\ M \\ S \end{pmatrix} = \mathbf{T}\begin{pmatrix} R \\ G \\ 0 \end{pmatrix} = \begin{pmatrix} L = T_{11}R + T_{12}G \\ M = T_{21}R + T_{22}G \\ S = T_{31}R + T_{32}G \end{pmatrix}, \quad \begin{pmatrix} L_Y \\ M_Y \\ S_Y \end{pmatrix} = \mathbf{T}\begin{pmatrix} Y \\ Y \\ 0 \end{pmatrix} = \begin{pmatrix} L_Y = T_{11}Y + T_{12}Y \\ M_Y = T_{21}Y + T_{22}Y \\ S_Y = T_{31}Y + T_{32}Y \end{pmatrix} \tag{5}$$

where $\mathbf{T}$ is the transformation matrix. Color matching exists between the two halves of the bipartite field if

$$\begin{cases} L = L_Y = T_{11}R + T_{12}G = T_{11}Y + T_{12}Y \\ M = M_Y = T_{21}R + T_{22}G = T_{21}Y + T_{22}Y \\ S = S_Y = T_{31}R + T_{32}G = T_{31}Y + T_{32}Y \end{cases} \tag{6}$$

In Nagel anomaloscope $S = S_Y = 0$, for which the set of two equations has to be considered. In the case of dichromates, protanopes and deuteranopes, the equation system becomes one equation for each of the two types of dichromatism, that represent a straight line for the L cones of deuteranopes:

$$\frac{R}{G} = -\frac{T_{12}}{T_{11}} + \left(1 + \frac{T_{12}}{T_{11}}\right)\frac{Y}{G} \tag{7}$$

and analogously for the M cones of protanopes:

$$\frac{R}{G} = -\frac{T_{22}}{T_{21}} + \left(1 + \frac{T_{22}}{T_{21}}\right)\frac{Y}{G} \tag{8}$$

Stimuli (R, G, 0) and (Y, Y, 0), matched for deuteranopes or protanopes, satisfy the equations (7) or (8), respectively. For normal trichromat observers, the two equations (7) and (8) have to be satisfied simultaneously, and this happens for the intersection point of the two straight lines. For normal trichromat observers there is only one color match. For deuteranopes and protanopes all the points of the corresponding straight lines represent good color matches. The identification of the lines classifies the type of color blindness.

The heterochromatic matching of the two parts of the field, a part yellow and the other part with the color produced from a mixture of green and red, concerns the luminance and for hypothesis presents the minimum border distinction. This matching regards all the observers, dichromates and trichromat. The heterochromatic matching is described by a single equation, and regards the Y tristimulus component in the XYZ in the reference frame of CIE. The equation in this case is:

$$Y_{\mathrm{CIE},R+G} = U_{21}R + U_{22}G = Y_{\mathrm{CIE},Y} = U_{21}Y + Y_{22}Y \tag{9}$$

where matrix **U** implements the transformation from RGB reference frame to CIE XYZ reference frame.

This last equation can be rewritten as follows:

$$\frac{R}{G} = -\frac{U_{22}}{U_{21}} + \left(1 + \frac{U_{22}}{U_{21}}\right)\frac{Y}{G} \tag{10}$$

Equation (7), (8) and (10) represent linear equations whose slopes are different depending on the observer (normal, dichromats and anomalous). All these lines cross the point $Y/G = R/G$, i.e., $Y = R = G$. The extension of the straight line and the slope characterize the considered observer.

As an example of the use of these tests we consider the case of a deuteranopic observer in comparison, if useful, with a normal trichromat.

Figure 1 shows the window related to the first test where the observer has defined his minimum border detection. The result of this trial is shown in figure 2, where the red circular line show the shift of the luminous efficiency function of the considered observer with respect the standard CIE 1924 photometric observer. As well the normal observers show a similar shift, but in different directions, depending on the yellowness of the crystalline lens and the macular pigmentation.
Figure 3 shows the ordering of the deuteranope observer, where the typical regular jumps made by the deuteranope can be immediately seen.
Figure 4 shows the connection on the chromaticity diagram of the considered color samples made by the deuteranope observer displayed in Figure 3. On the right of Figure 4, inside a red rectangle, is shown an enlargement of the region of the considered color samples, where the connection is clearer. In both figures the deuteranopic confusion lines (green lines) are overlapped showing agreement between these lines and the sample interconnection.
The test related to the achromatic appearance of particular spectral lights show a windows reproduced in Figure 5. At the top, the maximum saturation colors belonging to the sRGB gamut are shown. Among these, the observer has to select those color appearing achromatic, if existing. Protanopes and deuteranopes have two colors appearing achromatic, which are mutually complementary and belong to a confusion line. The normal trichromats have no achromatic in this gamut. Figure 6 shows the response of a deuteranope.
The test mimicking the Nagel anomaloscope shows a window where the observer first select a mixing of green and red light and then search for a matching of this color with that of a yellow light, if exist (Figure 7). This operation is repeated many times in correspondence to as many choices of green-red mixtures. If these matches exist, the fraction R/G and Y/G are recorded and plotted in a diagram (Figure 8).
Figure 9 shows the same diagram related to a deuteranomalus. Figure 10 shows the data related to heterochromatic matching of a normal trichromat.

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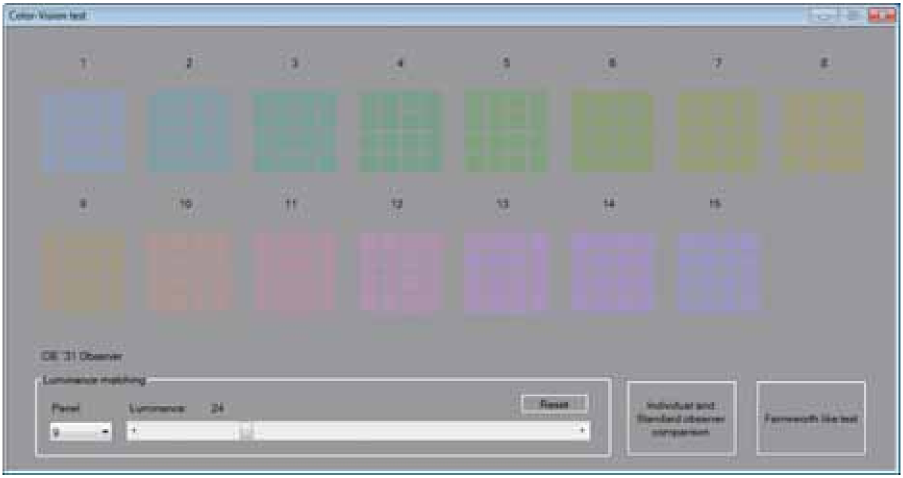

Fig. 1 -.Fifteen color patches with an internal fragmentation on a uniform grey. The luminance of these patches and of the ground is the same for the CIE 1924 standard photometric observer. The user must modify the luminance of the color patches with that of the ground by minimizing the perceived border between color patches and background. The color patch is selected by clicking on the patch or by panel window. The luminance is modulated by shifting the Luminance cursor with the mouse.

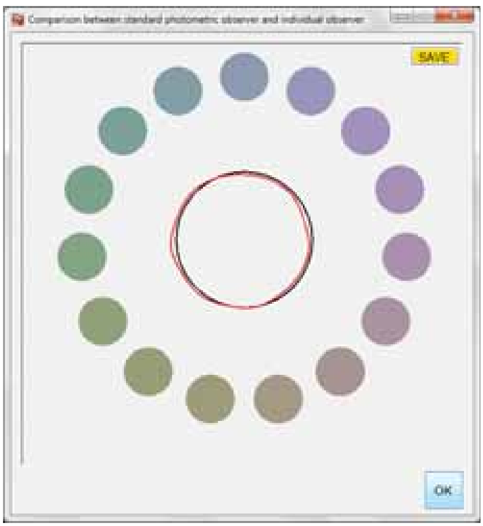

Fig. 2 - Plot of the luminance variations made in the experiment of Figure 1 represented by a circular line in comparison with a circle associated with the standard photometric observer. Any increment is the luminance is represented by a distance from the center greater than that of the circle and, conversely, any decrement by a minor distance. The difference between the circular line and the circle is representative of the difference between the user and the standard photometric observer. The origin of such a difference may be either a yellowing of the crystalline

lens or anomalies or dichromatism. The difference between the standard observer and individual observers are small, as in the case of yellowing of the crystalline lens due to aging shown here.

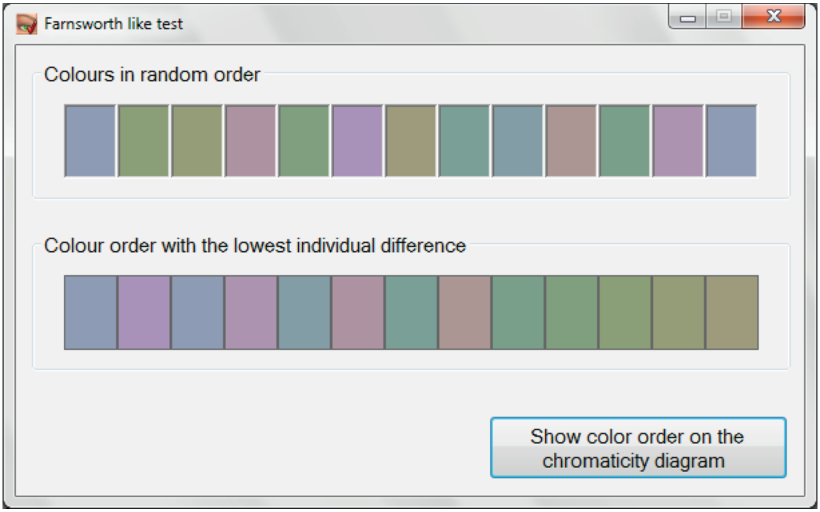

Fig. 3 - Color ordering made by a deuteranope. The user must order these color patches in such a way that any color has the minimum perceived difference with respect to the previous one. The choice of the color sample to put in the ordered sequence is made by clicking on the color sample and, for correcting a wrong shift, by clicking on the moved sample.

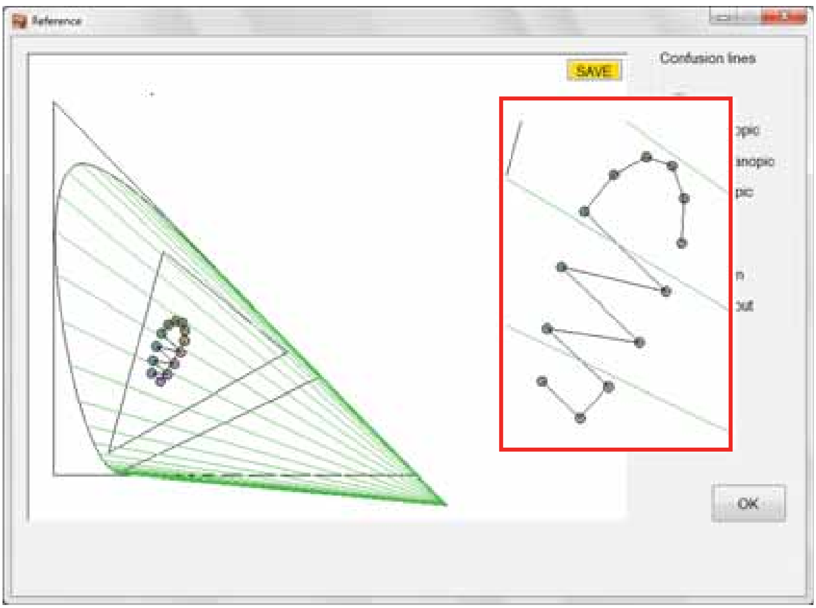

Fig. 4 - Chromaticity diagram CIE 1931 with a black line connecting the color samples of Figure 3 in the perceived order produced by the observer. This figure presents the case of a deuteranope. The green lines are typical deuteranopic confusion lines, to be compared in direction with the jumps of the black line connecting the color samples. The particular line connecting the color samples is reproduced enlarged inside the red rectangle.

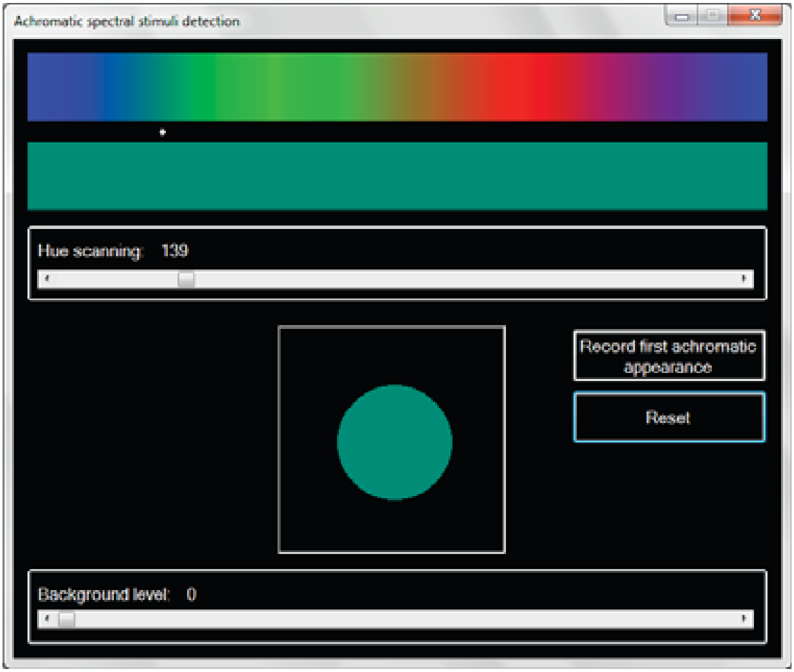

Fig. 5 - Achromatic spectral stimuli detection. The selected color appears achromatic for a deuteranope

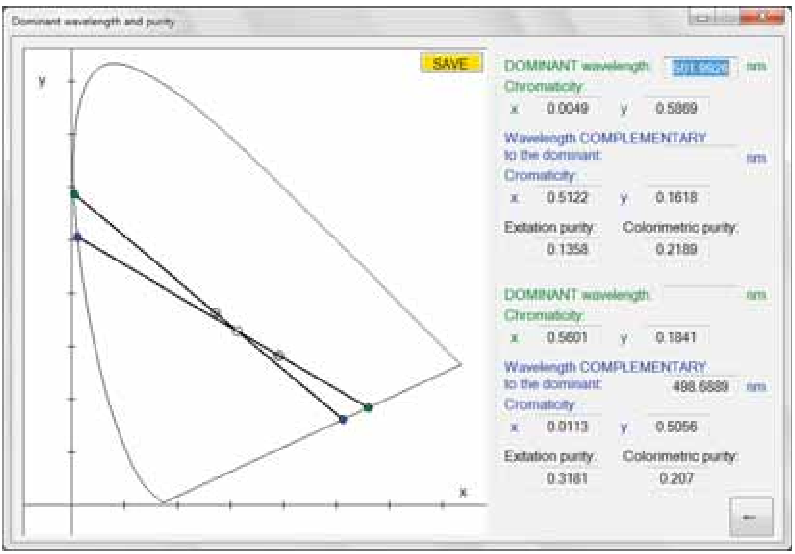

Fig. 6 - Maximum saturated colors in sRGB gamut appearing achromatic to a deuteranope. These two colors belong to a straight segment containing the Equal energy white, as expected, and define 502 nm and the complementary to 499nm as achromatic wavelength of the considered deuteranope observer.

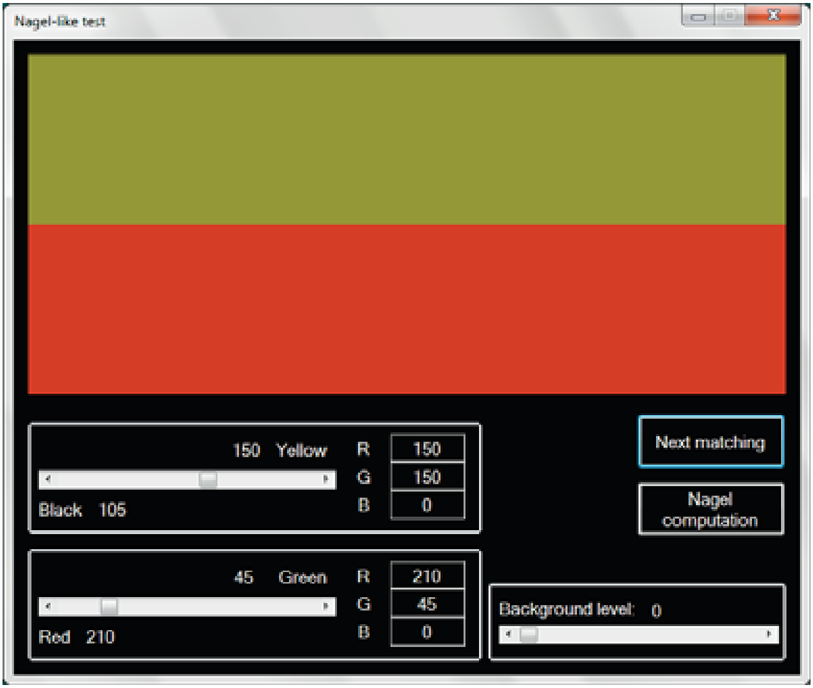

Fig. 7 - Nagel like anomaloscope. A yellow color is at the top while below is a mixture of red and green matching the yellow for a deuteranope.

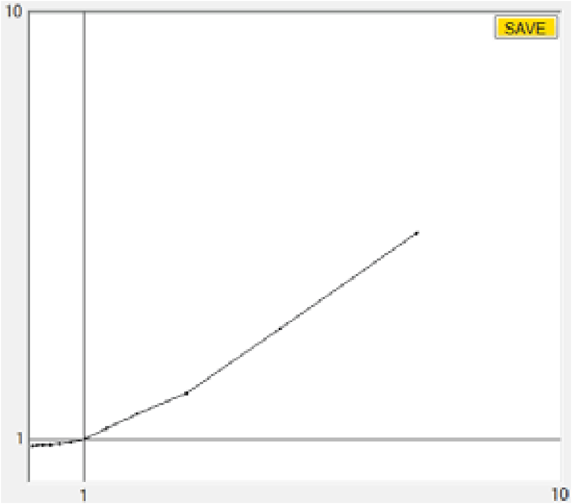

Fig. 8 - Empirical data produced by a deuteranope that should belong to the straight line of equation (7). The line is next to a broken line the cause of which requires the study of most observers. Certainly, the presence of the S cones conditions the matching.

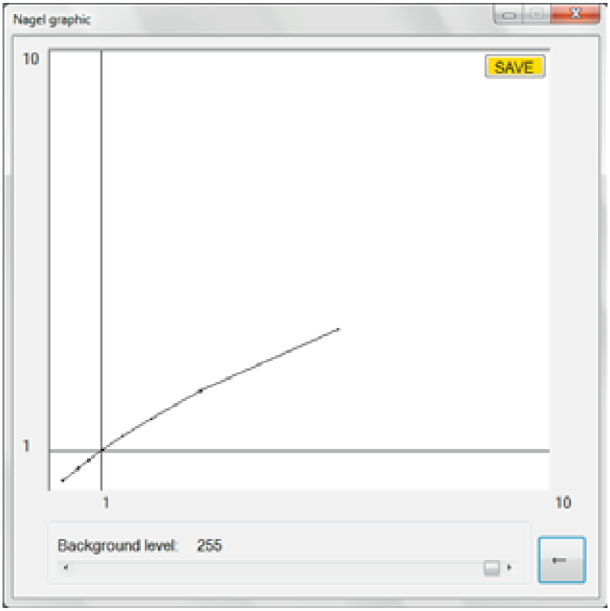

Fig. 9 - Empirical data of a deuteranomalus, who has color matching only inside the drawn segment. The line is a little bit bent.

Fig. 10 - Empirical line representing the heterochromatic matching of a normal trichromat, whose equation is (10). The line is next to a broken line the cause of which requires the study of most observers. Certainly, the presence of the S cones conditions the matching.

Colour vision wearing sport glasses

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1. Introduction

When we think about something visual a coloured image comes to our mind. This happens because the complex mechanisms of our vision give information about the colour of some objects or the environment automatically. Therefore colour should be interpreted in a way that corresponds to the levels of the complex system of our vision.

The triple definition of colour reflects to this complexity very well [1]. We can define colour as a physical stimulus, as the perceived sign generated by the stimulus in the eye and even as the perception built in the observers mind.

Physical stimulus is defined as electromagnetic radiaton of wavelengths between 380nm and 780nm. It depends only on the physical parameters of the object and the environment and does not depend on the observer at all.

The psychophysical definition explains the response on the stimulus generated in the organ of perception. Therefore at this level colour depends both on the stimulus and the sensitivity of the receptors in the eye.

The psychological colour occurs in the observers mind and eventually that is the perception that we can use for further operations such as comparing, naming, remembering, etc. This perception is built up from the psychophysical colour, the processes in the neural system and other mechanisms such as learning, memory, etc.

During the design process of an experiment that aims to measure parameters of human colour vision all these definitions and the connections between them should be considered.

Wearing coloured lenses can be considered as placing colour filters between the observed objects and the observer hence as the modification of the physical stimulus. As a brief model: assuming that the spectral sensitivity of the cones in the eye does not vary, modifying the stimulus that reaches the eye can show effect on perception [2].

Nowadays glasses with coloured lenses are available for many purposes such as fashion, sport, special work-facilities, etc. Sport activities are usually related with fast movements and quick decisions where reaction time and colour discrimination are important parameters.

The aim of the measurement detailed in this paper is to observe if three commercially available sport glasses affect on colour discrimination or not.

2. Measurements

Measurements were done in the Visual System Laboratory at the Department of Mechatronics, Optics and Mechanical Engineering Informatics, Facoulty of Mechanical Engineering, Budapest University of Technology and Economics

2.1. Filters

Three glasses were analysed: two designed for skiing and one designed for riding bicycle. The hues of the lenses are purple, orange and yellow. There is a main possibility on grouping the lenses according to their spectral parameters.

Fig. 1 shows the spectral transmission of the purple filters (further on F1) that has a steep entering edge at 400-435 nm from 0% to 75% and for higher wavelengths in the visible spectral range the transmission varies in the range of 30% to 100%. Hence F1 can be considered as broadband filter as above 400 nm there is no range that filters entirely.

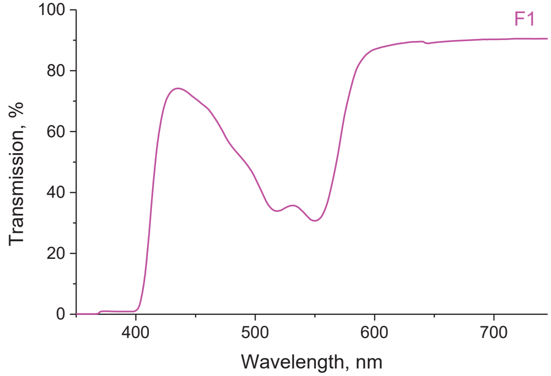

Fig. 1 - Spectral transmission of the purple filter (F1)

Besides Fig. 2 shows the spectral transmission of the yellow and the orange filters (further on F2 and F3). Both of them can be considered as highpass filters as the transmissions are uniquely defined by an entering edge.

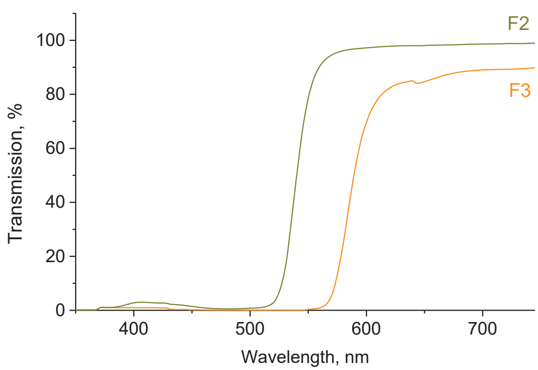

Fig. 2 - Spectral transmission of the yellow (F2) and the orange (F3) filters

2.2. Subjects

Two subjects were involved. Both of them were 27 years old, one male and one female. Subjects were examined with anomaloscope in order to declare that they are good colour observers and do not have any colour vision deficiency. Based on the anomaloscope test results subjects were considered as standard colorimetric observers [3]. Fig. 3 shows the spectral sensitivity curves of the standard observers **Errore. L'origine riferimento non è stata trovata.**.

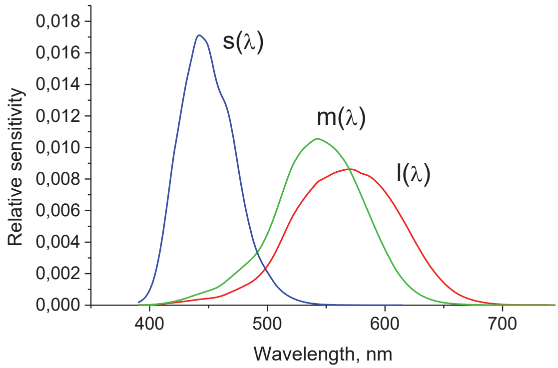

Fig. 3 – Spectral sensitivity of the short, middle and long wavelength-sensitive cones of a standard colorimetric observer

A measurement with unaided eyes (further on F0) was always considered as reference.

2.3. Chromatic adaptation

In order to avoid the transient effects after putting on the glasses measurements started only when the colour constancy, hence chromatic adaptation could be assumed. Total chromatic adaptation was assumed when subjects perceived a white surface perfectly achromatic white. Subjects had at least 5 minutes for chromatic adaptation before starting the measurements.

2.4. Ellipse Test

Subjects had to accomplish the Ellipse Test of the Cambridge Colour Test [4] that provides colour discrimination ellipses as the result of the evaluation process. During measurements 3 points (further on Field Points, see Tab. 1) were selected as the centers of colour discrimination examination.

Field Point	u'	v'
1	0,198	0,469
2	0,193	0,509
3	0,204	0,416

Tab. 1 – Coordinates of the Ellipse Field Points in CIE Lu'v' colour space

Subjects had to define the orientation of Landolt C figures while the cromaticity difference between the background and the figure reduced. This was repeated towards 8 vectors spaced at 45 degree intervals at each Field Points.

Fig. 4 shows two figures as example of the figures represented during measurements.

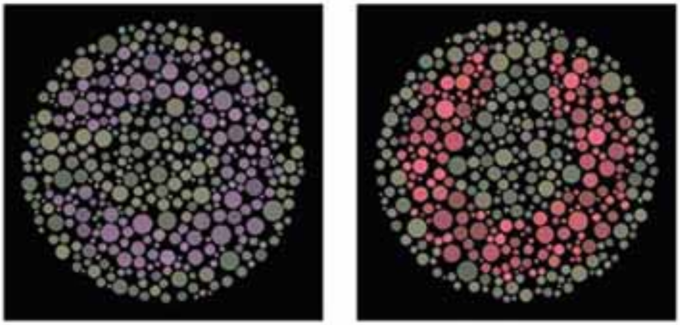

Fig. 4– Landolt C figures of Cambdridge Colour Test in different orientations

The vectors show the smallest distance in CIE Lu'v' colour space that subjects could discriminate hence the just-noticable colour differences assigned to a Field Point and a direction. Ellipses were fitted using least squares method to the measured points. Altogether subjects could not discriminate chromaticity within points in the areas of the ellipses.
Since CIE Lu'v' colour space was designed aiming to assign equal distance to equally perceived chromaticity difference, the colour discrimination ellipses of an ideal colour observer should be circles with a radius as small as possible. Extension of the ellipses towards any direction shows that colour discrimination did not worsen equally in the whole spectral range.
Subjects viewed the screen from 3,26 meters that provided 5° angle of view. The laboratory was shaded so there was no light source besides the display.

3. Analysis

In order to show the effect of the lenses analysis of variance (further on ANOVA [6]) was executed respectively to the number of relevant factors. The experimental design was defined by three factors: the Field Points (see Tab. 1), the Filters and the Subjects. Each measurement was repeated twice with each set of factors.
The highpass filters and the broadband filter were analysed separately but the experimental design was equal regarding the number of the factors. Therefore in both cases a three-way ANOVA was executed.
The variable of the analysis was the length of the longer axis of the colour discrimination ellipses.
However measurements were repeated twice in order to be able to show the effect of interactions, both ANOVA showed that there was no significant interaction between the factors (significance level between 0,01 and 0,05). Therefore in both cases the errors of interactions were added to the residual and a new ANOVA was executed regarding only the effects of the factors.

3.1. Broadband filter

Purple lenses have a vivid colour. The chromatic adaptation occurred easily after less than 3 minutes of adaptation.

Fig. 5 shows the results of one of the subjects and the colour gamut boundary of the applied display.

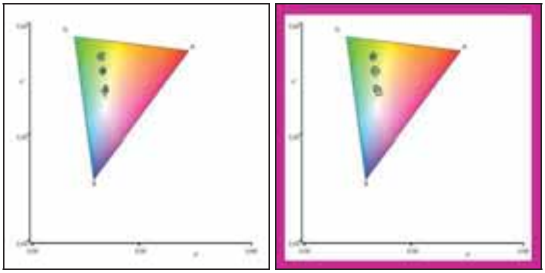

Fig. 5 – Colour discrimination ellipses of measurements F0 (left) and F1 (right) in CIE Lu'v' colour space

The filters extended the ellipses proportionally there was no assigned direction of extension.

The factors of the ANOVA were the following: Field Points (see Tab. 1) Filters (F0 and F1) and Subjects (1 female, 1 male). Each measurement was repeated twice, hence altogether 12 values were analysed.

Tab. 2 shows the ANOVA table where the purple lenses were compared with the unaided results.

Variation	SS	d.f.	MS	F
Field Points	0,0003	2	0,0001	2,9903
Filters	8,74E-05	1	8,74E-05	1,8185
Subjects	0,0005	1	0,0005	11,0696*
Residual	0,0002	19	8,40E-06	0,1749
*significance level between 0,01 and 0,05				

Tab. 2 – ANOVA table – analysis of the purple (F1) filters

The results show that there is no significancy regarding the ellipse fields and the filters, but there is significant difference between subjects (significance level between 0,01 and 0,05).

3.2. Highpass filters

The colour of the yellow lenses was vivid and light. Wearing them less than 1 minutes was enough for chromatic adaptation. However, wearing the orange lenses after 10 minutes subjects still did not perceive the colour of a white surface as achromatic white.

Fig. 6 shows the results of one of the subjects and the colour gamut of the applied display.

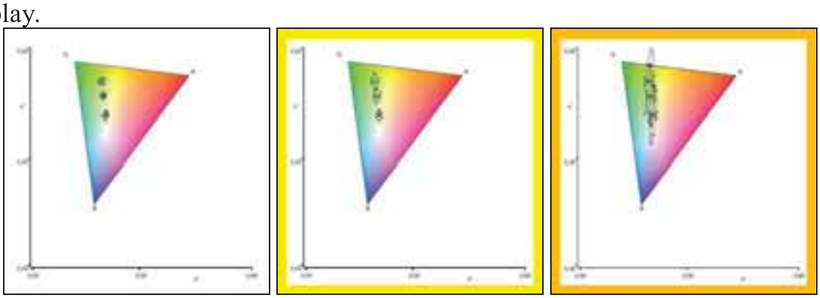

Fig. 6 – Colour discrimination ellipses of measurements F0 (left), F2 (middle) and F3 (right) in CIE Lu'v' colour space

The colour discrimination ellipses extended towards the Blue point of the gamut of the display while the small axes towards the Red-Green points did not change significantly.
The factors of the ANOVA were the following: Field Points (see Tab. 1) Filters (F0, F2 and F3) and Subjects (1 female, 1 male). Each measurement was repeated twice, hence altogether 36 values were analysed.
Tab. 3 shows the ANOVA table where F2, F3 and F0 were considered.

Variation	SS	d.f.	MS	F
Field Points	0,1609	2	0,0805	0,0141
Filters	55,4454	2	27,7227	4,8701*
Subjects	1,5015	1	1,5015	0,2638
Residual	128,4007	30	4,2800	0,7519
*significance level between 0,01 and 0,05				

Tab. 3 – ANOVA table – analysis of the yellow (F2) and orange (F3) filters

The results show that the filters affected the variable significantly, which means that wearing coloured lenses modified the magnitude of the just-noticeable difference at each ellipse field.

4. Conclusions

As a main conclusion it can be stated that highpass filters affected the just-noticeable difference of the subjects significantly. The direction of the extension of the ellipses can be explained with the spectral parameters of the lenses. F2 cuts off the main part of the range of sensitivity of the short wavelength-sensitive cone while above the wavelength of the entering edge of F3 $s(\lambda)$ has less than 20% of sensitivity. This explains that the colour discrimination of the subjects worsened towards the blue point of the display. Since the filters pass light in the range of sensitivity of $m(\lambda)$ and $l(\lambda)$ the red-green discrimination was not affected and the ellipses did not change significantly.
The result that F1 did not affect on colour discrimination significantly can be explained with its broadband aspect.
An additional result is that the ANOVA showed significant difference between subjects. However the anomaloscope test proved that subjects have no colour vision deficiency so they could have been be considered as equals, the Cambridge Colour Test can show more shaded differences. It is notable that even these differences lost significancy on the effect of the highpass lenses.

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Ideal Locus of the Green Light in Imam Redha's Holy Shrine [1] (Iran, Mashhad)

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1. Introduction

At the beginning of their account of the mystical experience, Namjmuddin Kubra, Najm al-Din Razi, and Ala ud-Daula Simnani, all referred to the "paying the way" (*Tei-e Tarigh*) as the motivation for the devotee in his pilgrimage from the inner darkness into the truthful lightening (He brings them out from darkness into the light. (2/257))[2]. Indeed, this pilgrimage from blindness into the certitude of enlightenment is metaphorically symbolized in the exodus from the passionate soul (the black colour) into the positive one (the white colour). On his way out of the darkness, the devotee inevitably enters into the darkness/lightening boundary where he might find the lightening veils visible. Only after paying this way, he would pass a seven-layer pilgrimage in which each layer is symbolizes an specific colour, and respectively each colour not only testifies his ability for the level, but also guide him on his way to the next level.

2. Najm Kubra, Najm Razi, Ala Simnani: The Mysterious Status of the Colourful Lights [Tab.1,2,3]

Although all the three wise person are similar in their idea of the way, its goal, and even the symbolical role of the colourful lights as the testifier and the guide for the devotee, there is a crucial difference between their ideas of the hierarchy of the colours. The difference deconstruction of which would lead one to their different methods, intentions, guidelines, and even personal talent as the roots. Indeed, it is obvious that there is no unique, undisputable interpretation of the colours; and so, methodologically, it is wrong to simply name a colour and insensitive to the differences; put all the mystical conceptions together. The following tables explain the different meaning of the colours in three Theosophists:

Colour	Meaning
Black	Darkness and the eternal blindness
Dark blue	Sensualism
Yellow	Devotee's weakness on the way
Red	Magnanimousness
Green	The living soul

Tab. 1 – the colourful lights in Najm Kubra

Colour	Meaning
White	Symbol of Islam
Yellow	Symbol of Belief
Dark Blue	Symbol of benevolence
Green	Symbol of the Righteous Soul
Azure Blue	Symbol of Faith
Red	Symbol of the True Knowledge

Black	Symbol of the Dionysian Love

Tab. 2 – the colourful lights in Najm Razi

Colour	Meaning
Grey	The Corporal (The Adam of Human-Being)
Blue	The Sensual (The Noah of the Human-Being)
Red	The Heart-full (The Abraham of the Human-Being)
White	The Secret-full (The Moses of Human-Being)
Yellow	The Soul-full (The David of Human-Being)
Black	The Covert (The Jesus of Human-Being)
Green	The Rightful (The Mohammed of Human-Being)

Tab. 3 – The Colourful Lights in Ala Simnani

It is worth noting that though there is a difference between the status of the green light's in the hierarchy, Simnani's conception of it is in accordance with the Najm Kubra and Najm Razi's.

While Kubra and Razi simply focused on the the explanation of their own mystical experience (to see the seven-layer colourful status), Simnani in addition to the explanation, attempted to hermeneutically interpret the various colourful stages and to explore the innermost meaning of each colour, namely the prophets to whom these colours belong.

3. Ala Simnani: Hermeneutics of the Mysterious Status of the Colourful Lights

In the view of all the three theosophists, colours are hierarchically ordered. However, Simnani recognized that even within each individual colour one might find an hierarchical order. In the other words, i.e. while the red light is placed above the Blue and bottom of the White colour, due to its accordance with the Abrahamic status of humanity –for which Abraham the prophet is the ideal example, who could realize it in his corporal body- any devotee is capable of the light only to the extent that his existential potentiality is capable for.

In addition, the mystical importance of the light is functionally subordinate to its distance from the physical world. So, as the colour get closer to the upper-world, and so farther from the lower-world, its mystical importance increases and eventually, in this hierarchy of importance, the green light, which is placed at the top, is the Secret of the Secret of the Secrets.

4. The Mysterious Status of the Colourful Lights in in the Architecture of Imam Redha's Holy Shrine (Hermeneutics of Location)

Pilgrimage is an individual activity based on an individual invoke. And the motivations for this activity involve the quest for physical or spiritual remedy, thankfulness to the master, evading the everyday life and harbor to the spirituality, and finally resoluteness in faith. Pilgrim, in this study is one who pays the way in order to resolute his faith. This is simultaneously subjective and objective journey which corporally leads him to a deeper spiritual understanding of the universe. Indeed, as is written in the shrines' pilgrimage, the pilgrim is basically intended to get closer to the Lord:

> Oh Lord, your slave is getting close to you through visiting your prophet's grandchild's shrine, and the host is obliged to his visitor and pilgrim, and you are the greatest and most merciful visited one [3].

In this study, Imam Redha's shrine in Mashhad is the final destination of the pilgrim. The shrine's architecture obviously shows that "this holy shrine is in its architecture a prototypical sample of the pilgrimage itself"[4] in which the pilgrim's journey is indeed his paying the way toward the *Qutb-i-Makan* (the local spiritual pole) (Imam Redha's tomb) has been ideally embodied in the architectural form. Like any other devotee, in this paying the way, the pilgrim first of all gets rid of his social everyday life. Then, exercising the rituals has been taught, he begins his paying the way and by traveling through inner and outer abodes, he attends his Imam's locus and get refined in order to get back home purified.

In this journey, the first catharsis happens when he forgets about all the materialistic affairs, which is indeed the most crucial part of the endeavor. This part, in which he detaches from the social affairs and so, all the outward dependencies, bridges his past, impure life and the healed future in which he believes. In other words, this subjective and objective journey represents invoke, presence, and return as the three pillars of the true journey toward the Lord.

The next step is to enter the holy shrine as the corporal as well as the esoteric destination. At the entrance of the holy shrine, the pilgrim whispers the *Idhn-i-Dokhul* (the abracadabra one whispers in order to receive Imam's admission for entering) and just after this step he is ready to enter. However, as the local spiritual pole (the Imam) is out of access, he must first pass several entrances, aprons, and porticos. Indeed, this represents a repetitious subject in the pilgrimage in his willingness toward spirituality.

In Imam Redha's shrine, as soon as the pilgrim's inner (see Fig.1), shallow light is connected to the eternal light of Imam, he feels an inward peace comparable with the peacefulness he might feel after a long, inquisitive struggle against his innermost darkness. In the Sufis terminology, this peacefulness is the result of eternal grace rather than the outcome of the devotee's struggle, and is attained only after he passed all the steps and became acquainted with the covert meanings of the upper world through his endeavor in ascending different steps and paying the way trustfully [5].

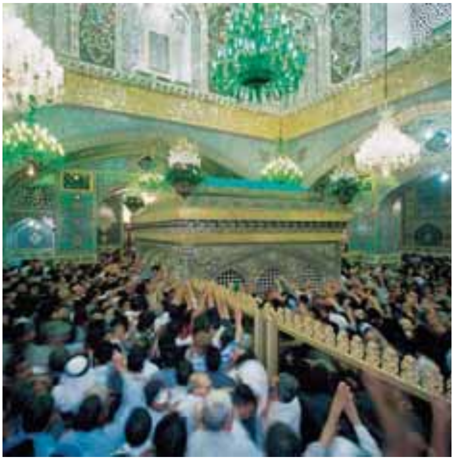

Fig.1. The Imam Redha's shrine

5. The Status of the Green Light: Status of Peacefulness

In Ibn Arabi, this peacefulness is a spiritual light which appears only when the devotee's heart is oracularly filled by the divine knowledge and faithfulness [6]. Thus, one might claim that this struggle leads the devotee to the hierarchical lights of enlightenment -through his contention with the inner darkness- and finally, to its 7th and the top stage, namely the green light. In his attainment of the green light, the devotee feels peacefulness in his heart, lightness in his chest, happiness in his soul, pleasure in his spirit, and spectrum in his eyes; all representing the spiritual liveliness which he could gain through his paying the way. This is why the green (the polar) light is so important. For it is the light of liveliness and is parallel to the heaven which is the threshold of the other world.

The green light is dispensable and by its virtue, the devotee is capable of paying the new horizons under the radiance of this inner light. Thus, the Lord's almightiness and divinity emanates and the most complete green-ness, shining from the divine heaven, surrounds his subjective sphere. Thereafter, the devotee feels deep tranquility, and the peacefulness –whose exemplifiers are the angels- enters his heart and brings it the green light, as the sign of the resoluteness and calmness of the soul. While the green light is the most compatible with the secret of secret of secrets, this most completeness of human existence, namely the Mohammedian, is purely green.

The final step of the way which the devotee feels as the green light and peacefulness in his heart is on the other hand the signifier of his stable locality (*Tamkin*), for he is now in his completeness of devotion and the Lord is the only inhabitant in his heart. Thus, one might claim that the highest position for the devotee is the locality rather than status. On the other hand, due to the presence of the pole of the location (*Qutb-e Makan*), the locality of the holy shrine is heightened into a trans-physical location, namely the loftiest location divinely called "the Location" (*Makan*). Hence, the green colour is "located" in the holy shrine and in other words, the shrine bears the ideal locality of the green light. Indeed, it seems that presence of the green light in the holy tomb and the green lightening over the reliquary shows this meaning.

It is worth noting that the peacefulness the devotee feels in the shrine is probably temporal and diminishes soon after his exodus of the shrine and this also endorse the ideal locality of the green light, for this is simply due to the location and not the devotee's innermost, authentic spiritual status.

6. The Truth of the Green Light: Mohammedian Truth, The Mysterious Status of *Velayat* (Friendship with God)

What is the secret of secret of secrets? In order to answer this question, one might first consider that according to the mystical account, all the creatures are basically rotted in the existential truth of the Mohammedian enlightenment, which on the other hand, is the comprehensive exemplification of all divine and material perfection [6]. As Ibn Arabi addressed in the Mohammedian Bezel,

> As Mohammed is the determination of the divine, and the determination of the essence of the Lord has been represented in his infinite representatives, the unique wisdom has been devoted to the Mohammedian logos. Hence, the divine representations are hierarchically classified on the basis of their kind, type, and individual; and so, some are covered under the spectrum of the other [7].

So, as the comprehensive exemplification of all the divine perfection, he is the exceptional individual in the world and no other divine representation could equal him. There is only the absolute, unrestrained essence of the divinity (the Lord) which is beyond any determination, relation, definition, and description, which posits above him. Furthermore, while his positive object (*Ein-e Thabete*) was the first one divinely blessed, the very individuality realized only through it. Hence, his divinity and positive object could gain the supreme individuality as a result of his connectedness to the unique essence of the Lord [8].

Although God the almighty is essentially needless, in order to emanate perfectly, his divine names are needy of different spheres. In other words, existence of all the creatures is the effect of the divine names' quest for appearance. On the other hand, all the divine names are themselves covered underneath of "Allah" which is the most perfect and comprehensive one. However, even appearance of "Allah" is due to the existence of a universal sphere which is capable of the comprehensiveness of the name of the Allah's successor in the world (Allah's *Caliph*), and the conveyer of his grace into the world. Due to the prophetic saying (*Hadith*) declaring that "the first thing created in the world was my spirit or, in other words, my light", Mohammedian soul is the comprehensive representative of the almighty Allah [9].

According to Ibn Arabi's pantheism, truth is hierarchically descended in the 5-steps process from the uniqueness of the Allah –as the hidden treasure- to the earthly materiality of human-being and the world [10]. indeed, Allah in his first descending from the status of uniqueness into the status of individuality emanates himself in the perfect man (*Insan-i Kamel*); the status, according to Quran and the divine and prophetic sayings is exclusively owned by prophet Mohammed, and hence Ibin Arabi calls this status -the first emanation of the truth- as the Mohammedian truth. In other words, Mohammedian truth is the emanation of the hidden treasure, and Allah sees his own face in his mirror. Thus, this status is called Allah's emanated name [11]. indeed, Mohammedian truth is the conveyer of the divine grace to the other lower general or particular names. Therefore, his existential light is like the great sun from which all the lights spring. This status is called as the First Nous, the Holy Spirit, or the Mother Book [of Universe] [12].Since as the first emanation of

the divine uniqueness, Prophet Mohammed's is the plenary of all the emanations, he is necessarily the inimitable individual throughout the universe. As noticed earlier, this is only the unique essence of Allah above him, and so, his individual status is the perfection of all the names' perfection [13].
The crucial point is while the Mohammedian truth is the outward manifestation of the prophecy, the divine kindness (*Velayat*) through which the friends of Allah (*awliya allah*) –namely, the 12 Shiite Imams who descends from the prophetic origin, and all the other people who are friends of god by virtue of their love for the 12 Imams- is the inward emanation of the prophecy. In other words, *Velayet* is the pillar of the prophecy and all the prophets are obliged to accept the *Velayat* of Prophet Mohammed [14].
Indeed, since the 12 Imams, who are immediately connected to the essence of Mohammedian truth, are the conveyers of *Velayat*, and while according to the theosophists' account of the hierarchy of the lights, it is first of all the green colour which conveys the secret of secret of secrets and emanates in the existence of the Perfect Man, namely the Mohammedian truth, it is now clear why Imam Redha's Tomb is enlightened by the green colour. (see Fig.2)

Fig.2. The Green light in Imam Redha's shrine

7. Hermeneutics of the Shrine's Locality (The Status of Location, The Status of Imam)

The Status of Location: The Status of the Green Light, Status of Peacefulness;
The Status of Imam Redha: Valiollah (Friend of God); The Secret of Secret of Secret of the Green Light

As noticed earlier, pilgrim at the entrance of the tomb (see Fig.3) stops and whispers the *Idhn-i Dokhu*l, saying:

> Dear Lord, I am now at the entrance of a doorway of your prophet's hall, to which entering without permission has been forbidden; as you said: "Oh, the Believers! Don't enter prophet's (and his descendants') house without permission". Oh, Lord, I resolutely testify dignity of the host who is buried here in this holy shrine, whether be dead or alive; although I know that the prophet and all his successors are eternally alive and you feed them. They see me here by the tomb and hear my greetings and answer me –while my

hearing is under veil by your ordinance and I cannot hear them. However, you mercifully let me the pleasure to commune my secrets. I first ask your permission and ask your prophet's permission. I also ask his successor, the peremptory Imam, Ali bin Musa Al-Redha and the angels who are always present here and are mandatory for the shrine to allow me enter the tomb. So, the prophet! Am I allowed to enter? Oh, the Imam! Am I allowed to enter? And the angels who are the agents of this holy shrine! Am I allowed to enter? Let me in, my dear master; let me in as you invite your best friends, for though I am not worthy of such an invitation, you are merited for such mercifulness [15].

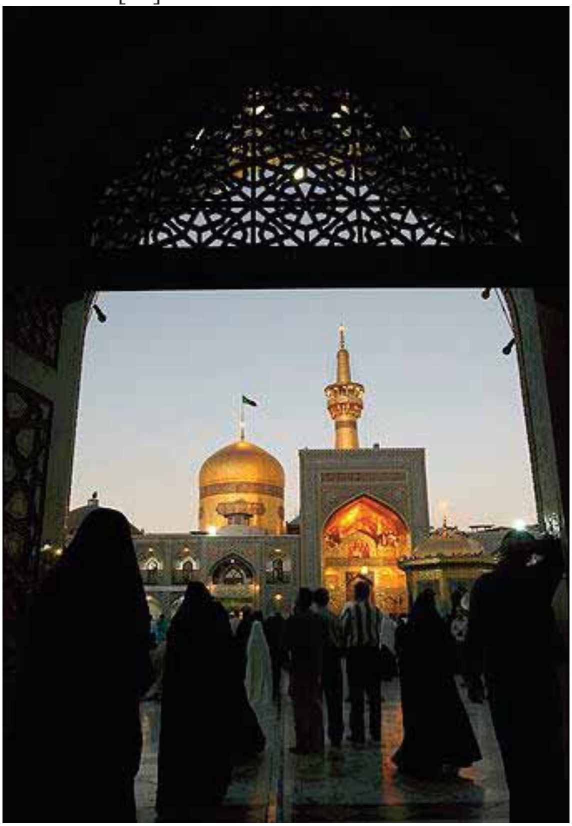

Fig.3. The Entrance of Shrine

This monologue at the entrance is really crucial. For he not only confess that Imam is eternally alive, but also testifies that he is present at the time and listens to the pilgrim's whispering and answers to him. In other words, by asking Imam's permission, he shows his testimony for Imam's presence in the time and place; and thus, unveils the status of Imam (the Perfect Man) as the general manifestation of the name "Friend of Allah" (*Valiollah*):

While all the creatures around the world are finally under the domination of the "Friend of Allah", Imam who is the general manifestation of the

> name, is capable of such an existential emanation which makes him the total cause of divine grace's streaming to the all parts of the universe.
> Thus, it is only through the mediation of Imam that all the creatures might connect to the Lord. This emanate spirituality of the Friend of Allah is called the Mohammedian Truth. Indeed, all the creatures are necessarily needy of the Friend of Allah and the Mohammedian Truth. And though most of them are ignorant, they belong to the *Valiollah*, are in his domination and oriented toward him [16].

8. The Golden Yellow Colour of the Dome

Iranians, from the ancient times to the present, attribute the Yellow colour to the sun and all the concepts metaphorically related to it. On the other hand, sun is in close relation with *Mihr* or *Mithra* who has been a predominant goddess of the ancient Persia. So, sacredness of the yellow colour in Iranian view is clear [17]. From the materialistic point of view, this colour is also the symbol of the gold, the most noble metal. Hence,

> As the 8th metal, and based on its essential nobility, gold is superior to all the other metals [18].

Gold's enlightening and transparency made it the symbol of "enlightenment, the Inner purity, and divinity". Even in different allegories it has been emphasized that when the human essence is boiled in a caldron, his senility and weakness disappears and he become "enlightened just like gold". It means that subliming into an incorruptible position, human being experiences perpetuity and become eternal just like gold [19].

Furthermore, in another ancient Persian spiritual religion, manichaeanism (whose doctrine is basically explained in colourful paintings), golden is the most sacred colour. However, the most interesting point here is the use of golden colour in painting the sky; for this is exactly similar to the use of this colour in order to cover the dome in the religious architecture. Indeed, due to saying that in divine painting, the colours detach from the real world in order to attach themselves to the superior reality, one might dare to claim that the golden sky represented in painting is indeed the symbol of spheres of meaning. It is more interesting when one realizes that in almost all the oriental schools of thought, sky is multi-layered. In Quranic view too, the sky is seven-layered in which transcending the layers leads to the decrease in materiality and increase in the enlightenment. In Islamic mystical teachings, the colour of sky is dark blue; however, transcending into the upper layers of the heavenly sky makes this colour more transparent and finally at the final stage, the most divine colour, namely the golden yellow, appears. Indeed, the golden sky painted in Iranian painting is not the exemplification of the real, materialistic sky, but an ideal, divine one.

Fig.4. Golden Dome of Shrine

Conclusion:
The Golden Colour of the Dome: The Mysterious and Material Ideal Locus of the Green Light in Shrine

Although what the architect does is eventually rooted in the categories discussed above, and he, either consciously or unconsciously, is capable of such meanings due to his existential deepness, it is not possible to enclose all the causes which might lead the architects to use the golden dome in holy shrines (see Fig.4). In other words, as the contemporary Iranian Theosophist, Mohammed Hussein Tabatabai, argues "there is no way to get to the right meaning unless through an intuition which is connected to the sacredness." Thus, there is no way other than intuition in order to interpret the meaning of the golden colour used in the dome of Imam Redha's holy shrine. This intuition should be connected to the divine unconsciousness of the architect for whom the golden colour has represented a purified understanding of the universe based on the mystical hierarchy of the colours.

References

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‘Italian blues’: Does bilingualism modulate colour categories?

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1. Introduction

Language specific concepts direct attention to certain perceptual attributes of reality. The universalist stance holds that imprints of perception and cognition are universal and as such are common across languages. In contrast, according to the Sapir-Whorf hypothesis of linguistic relativity, perception of the world is influenced by semantic categories of a person’s native language, whereby these categories vary across languages with few constraints.

Colour naming across languages is ideal for testing the predictions of both theories. In this domain, the universalist viewpoint is represented by the Berlin and Kay [1] hypothesis: (1) languages can contain up to 11 basic colour terms (BCTs) consistently appearing in a given language’s colour lexicon; (2) colour categories are organised around universal focal colours.

In comparison, according to the weak relativity hypothesis, advocated, e.g., by Roberson and associates [2,3], boundaries of colour categories vary cross-linguistically affecting colour perception and cognition.

Colour naming in bilinguals is a means of testing the two theoretical views. Of particular interest is whether bilinguals partition colour space differently in their two languages, and if yes, whether colour categories in their native language (L1) – focal colours and category boundaries – are modulated by categories in their second language (L2).

To our knowledge, studies on bilinguals’ colour naming and colour categorisation are few, but these converge in several findings with evidence of Whorfian effects:

- Bilinguals’ colour categories are less stable than those in L1 monolinguals; for BCTs their focal colours are shifted towards those of monolingual speakers of L2 (semantic convergence) [4–7];
- Bilinguals reveal a hybrid colour-naming that commingles the naming tendencies exhibited by the L1 and L2 monolingual groups but is not identical to either (e.g. use of modifiers vs. non-BTCs). Consensus in colour naming is increased among bilinguals, since they tend to use more frequently BCTs, probably due to a focus on what is shared across their two languages and/or a vocabulary loss affecting more differentiated and less frequently used terms describing subtleties of colour appearance [8-10];
- Perceptual distinction of colours – L1-like or L2-like – depends on several factors:
  (i) the level of L2 proficiency (major factor);
  (ii) the language used most frequently in daily activities;
  (iii) the length of immersion in L2-speaking environment (modulating factor), indicating that it is ultimately language exposure that drives the observed modulation in bilinguals’ colour cognition [11].

In the present study we explored a possible semantic shift of focal colours for 'blue' in Italian-English bilinguals. Recent psycholinguistic studies provide accumulated evidence that Italian has more than one BCT for 'blue', in accord with the weak relativity hypothesis. Notably, the number of the 'blue' BCTs appears to vary between regions exposed to different Italian dialects [cf. 12]: in Verona (Veneto region) the two identified BCTs are *azzurro* 'azure, light blue' and *blu* 'dark blue' [13-14]; in comparison, three BCTs denoting the BLUE area of colour space, *celeste* 'sky blue, light blue', *azzurro* 'medium blue' and and *blu* 'dark blue', are demonstrated for speakers in Florence (Tuscany) [15-16] and Alghero (Algherese Catalan dialect, Sardinia) [17]. The multiple Italian 'blues' are conjectured to have emerged in response to the cognitive need to differentiate between the colours of the sky and the water of the Mediterranean Sea [18,19].
The case of blues in Italian bilinguals is particularly interesting bearing in mind findings for Greek-English bilinguals [7]. In his study Athanasopoulos [7] estimated best exemplars (foci) of two Greek BCTs for 'blue', *ble* 'dark blue' and *ghalazio* 'light blue', using colours of the Munsell Mercator projection, i.e. fully saturated and varying in hue and lightness. Advanced bilinguals, with high proficiency in English and long acculturation, revealed a shift of the *ble* foci towards the *blue* focus of English monolinguals along the Munsell Value (lightness) dimension. Moreover, the focus of *ghalazio* appeared to be shifted away from the *blue*, to maintain the lightness perceptual distance between the native-language 'blue' foci.
In view of these findings, for Italian-English bilinguals we anticipated a semantic shift of *blu* 'dark blue' focal towards the medium-lightness *blue* focal, accompanied by corresponding shifts of *azzurro* and *celeste* away from of the *blue* focal (a Whorfian effect). We also explored the role of linguistic and socio-cultural factors (i)-(iii) indicated above.

2. Method

2.1. Participants

Participants were Italian monolinguals from Alghero, Sardinia (N=13; 7 females; 19–48 y.o.); Verona (N=15; 5 females; 15–19 y.o.), British English monolinguals (N=16; 12 females; 19–48 y.o.; Liverpool) and Italian-English bilinguals (N=13; 6 females; 22-58 y.o.; Liverpool). All had normal trichromatic colour vision as diagnosed with the Ishihara Pseudoisochromatic Plates [20]. None had reported any ocular disease, eye surgery, diabetes or use of a medication that could have affected colour vision.
Almost all bilinguals were either academic staff or university students. Level of their proficiency in English was assessed using the Nation Vocabulary Test [21]. This estimates vocabulary at five levels, ranging from the 2,000-word up to the 10,000-word level, with the score 80-90 (maximum) indicating advanced level [cf. 7]. In addition, information was obtained on the place of birth, age of L2 acquisition, duration of immersion in L2 environment and percentage of weekly English use. Table 1 shows that all, apart from three, were late bilinguals, i.e. have acquired L2 at the age of 6 years or later [22]. The majority of participants were originally from Central Italy, Lombardy and Emilia-Romagna, two from Sardinia; one early

bilingual was born in North-West England, UK. Advanced bilinguals (N=8), with Nation Test scores (78-90), are highlighted in bold.

Bilinguals	**DB**	**EB**	ER	**FA**	**FB**	FS	**MG**	**MZ**	NM	PD	**PG**	SC	**VA**
Gender	M	F	F	M	M	F	M	M	F	M	F	M	F
Age	35	35	24	47	29	32	30	42	22	56	58	22	32
Immersion duration	**10 yrs**	**10 yrs**	2 mo	**17 yrs**	**3 yrs**	11 mo	**25 yrs**	**16 yrs**	4 mo	5 yrs	**38 yrs**	4 mo	**6 mo**
Nation Test score	**88**	**90**	74	**85**	**78**	67	**85**	**89**	72	72	**89**	66	**84**
Age of L2 acquisit.	**6**	**8**	23	**14**	**8**	11	**0***	**6**	8	5*	**3***	14	**15**
%Weekly English	**95**	**90**	70	**95**	**80**	80	**90**	**80**	70	60	**80**	70	**80**

Tab. 1 – Summary of the bilinguals' details. In bold are advanced bilinguals; * indicates early bilinguals

2.2. Stimuli

From *The Munsell Book of Color* (glossy edition), we employed eight charts embracing the BLUE area, with Hue 7.5BG, 10BG, 2.5B, 5B, 7.5B, 10B, 2.5PB, 5PB (illustrated in Figure 1). Value of the Munsell chips varied between 2–9 and Chroma varied (even number notation) from 2–10, or 12 in 10B, 2.5PB, 5PB.

Fig. 1 – Examples of three BLUE area Munsell charts. Photo Credit: http://colorcard.net.cn/CMYK_Munsell_content.htm

For purposes of further analysis, Munsell coordinates of the stimuli (N=237) were re-notated (http://www.cis.rit.edu/research/mcsl2/online/munsell.php) in the CIELAB space, as presented in Figure 2.

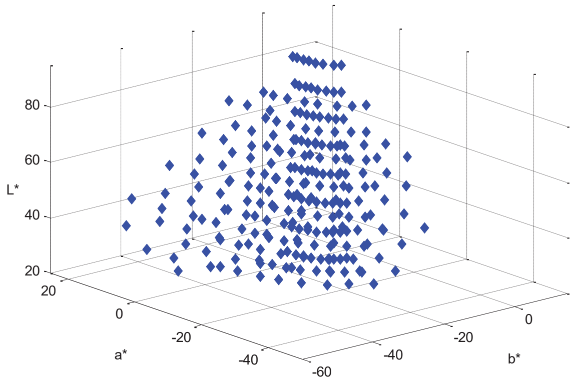

Fig. 2 – Munsell BLUE area stimuli (N=237) presented in the CIELAB space.

2.3. Procedure

After adaptation to mesopic lighting, charts were presented in a viewing booth under D65-metameric illumination (Just Normlicht Mini 5000; Fa. Colour Confidence) suspended 40 cm above the chart and delivering a 30 x 25 cm light area (Figure 3). Each chart was presented one-by-one in a fixed order (as indicated above).

Fig. 3 – Viewing booth with standardised lighting of Munsell charts.

For labelling Munsell chips, unconstrained colour naming method was used: participants were requested to name each chip with the most appropriate term, including hue terms (e.g. Italian: *blu, azzurro, indaco*; English: *blue, turquoise, indigo*), compound terms or terms with modifiers (e.g. Italian: *blu notte, blu scuro, chiaro turchese*; English: *sky blue, pale blue, sea blue*). Participants worked row by row across the chart from top to bottom; colour names were recorded by hand immediately and exactly as the participant said them. Following this, across all eight charts, the participants indicated the 'best example', focal colour, of the terms *blu, azzurro* and *celeste* (Italian) or *blue* and *light blue* (English). The focal colours were noted on the response sheet and coded by their Munsell Hue, Value and Chroma.
In their two languages, bilinguals were tested on separate days, with the counter-balanced order of Italian and English sessions. During the session the experimenter provided the instruction and communicated with the participant in the corresponding language.

3. Results

3.1. Italian monolinguals vs. English monolinguals: Focal colours

Figure 4 illustrates Munsell maps of Italian monolinguals' focal colours for *blu* and *azzurro*, superimposed on focals for the English *blue* by English monolinguals. The size of the symbol indicates the relative number of participants who have chosen the corresponding chip as the focal colour. It is worth noting that the present range of English *blue* focals – 10B 5/12; 2.5PB 5/8–12; 5PB 4/10–12 and 5PB 5/12 – includes the foci for *blue*, with a purplish tint, reported earlier, i.e. 5PB 4/12 [23] and 2.5PB 5/12 [24,25], obtained using the Munsell Mercator projection array of fully saturated colours.

3.1.1. Blu vs. *Blue*

The high consensus focals for English *blue* and Italian *blu* are similar in Hue, both varying between 10B, 2.5PB and 5PB. However, the focals of the two terms differ in lightness, with Value 4 or 5 for *blue*, compared to definitely darker *blu* with Value 2–3:

blu:	Hue:	10B–5PB;	Value: 2–5;	Chroma: 4–12
blue:	Hue:	5B–5PB	Value: 4–5	Chroma: 8–12.

3.1.2. Azzurro vs. *Blue*

As is shown in Figure 4, the dominating *azzurro* focal, 10B 5/12, maps onto the 'vivid' *blue* focal. The focal ranges of the two terms overlap only partly though, with *azzurro* being more bluish (azure) than *blue* and including lighter colours (Value 6–7):

azzurro:	Hue:	7.5B–2.5PB	Value: 4–7	Chroma: 8–12
blue:	Hue:	5B–5PB	Value: 4–5	Chroma: 8–12.

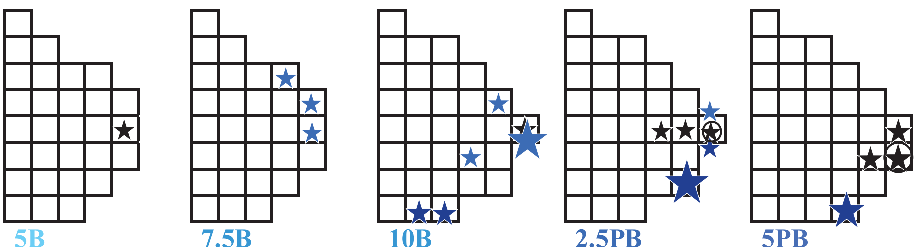

Fig. 4 – Munsell charts with mapped focals of *blu* (★) and *azzurro* (★) for Italian monolinguals superimposed on focals of *blue* for English monolinguals (★). The size of the symbols indicates relative number of participants' choices. Encircled ★ in 2.5PB is the focal *blue* estimated in [24,25] and in 5PB the focal *blue* estimated in [23].

3.1.3. Celeste vs. *Light blue*

Celeste was used rather frequently by the Algherese participants but not as frequent *blu* or *azzurro*; its focal range is more variable and comparable to that of the English non-BCT *light blue*. Figure 5 illustrates focal colours for *celeste*, in comparison with *light blue* focals. The dominating *celeste* focal, 7.5B 7/8, maps onto one of the (frequently chosen) *light blue* focals. The focal ranges of the two 'sky blue' counterparts differ partly though, with the *celeste* choices extending to aqua (2.5B) and being more saturated:

celeste:	Hue:	2.5B–2.5PB	Value: 5–7	Chroma: 8–12
light blue:	Hue:	5B–2.5PB	Value: 6–8	Chroma: 6–10.

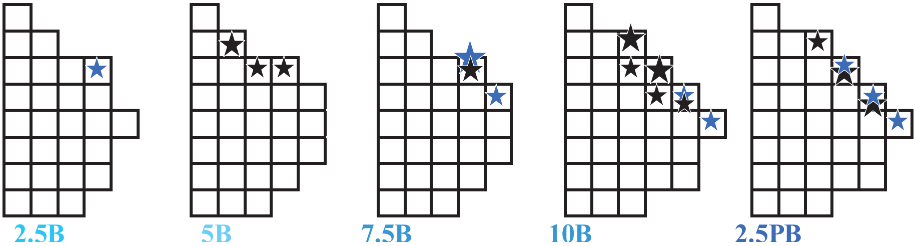

Fig. 5 – Munsell charts with mapped focals of *celeste* (★) for Italian monolinguals superimposed on focals of *light blue* (★) for English monolinguals. The size of the symbols indicates relative number of participants' choices.

3.1.4. Centroids of focal colours

Table 2 and Figure 6 present CIELAB coordinates of centroids of individual choices of focal colours by Italian and by English monolinguals. The centroids confirm that *blu* is comprehended by Italians as 'dark blue'; *azzurro*, in comparison, is cognate to English *blue*, while *celeste* has its close counterpart in English *light blue*.

Monolinguals	Colour term	*L**	*a**	*b**
Italian	*Celeste*	63.93	-11.07	-39.58
	Azzurro	54.65	-10.65	-45.66
	Blu	28.45	4.07	-41.53
English	*Light blue*	72.08	-8.02	-31.47
	Blue	47.21	2.07	-49.30

Tab. 2 – CIELAB coordinates of the centroids of focal colours for 'blue' for Italian monolinguals (Alghero) and English monolinguals (Liverpool)

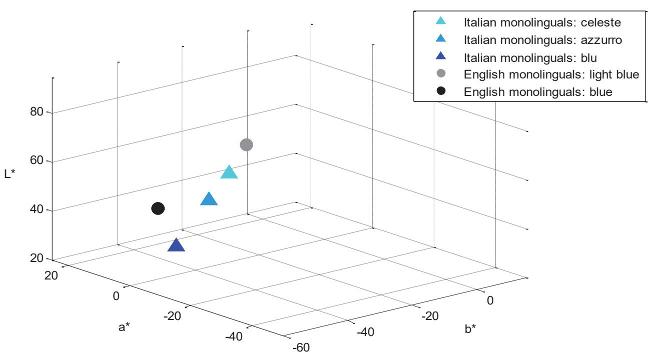

Fig. 6 – CIELAB colour space: Centroids of focal colours for the 'blue' terms for Italian monolinguals (Alghero) and English monolinguals.

3.2. Bilinguals: Focal colours in Italian and in English

3.2.1. *Blu* & *Azzurro* (Italian) vs. *Blue* (English)

Figure 7 shows mapping, on the Munsell BLUE charts, of bilinguals' focals of *blu* and *azzurro* (L1) and *blue* (L2). Frequently chosen focals of all three terms vary in Hue between 7.5B, 10B, 2.5PB and 5PB, being similar in this to the corresponding focals for Italian and English monolinguals (see also Figure 4).

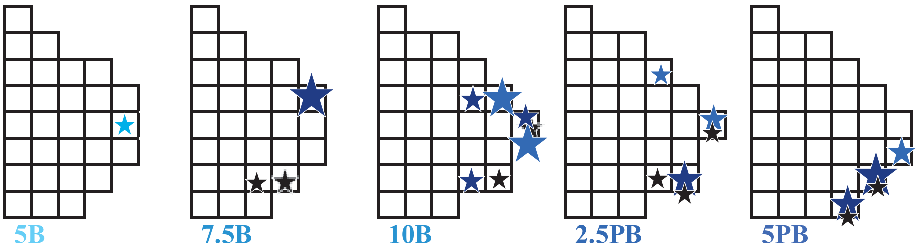

Fig. 7 – Bilinguals: Munsell charts with mapped focals of *blu* (★) and *azzurro* (★) in Italian superimposed on their focals of *blue* (★) in English. The size of the symbols indicates relative number of participants' choices.

3.2.2. *Celeste* (Italian) vs. *Light blue* (English)

For Italian-English bilinguals *celeste* is an English counterpart of non-basic *light blue*. Choices of *celeste* focals are spread in Value from medium to very light colours, as do focals of English *light blue* (Figure 8). It is worth noting that *celeste* was named less frequently by bilinguals; also, its focals spread across less BLUE charts in Hue, but have higher lightness and extend to very low Chroma, compared to the Algherese monolinguals' choices. In addition, some bilinguals remarked that *celeste* denotes the same colour as *azzurro* and they hardly use it, apart from when alluding to the 'heaven' meaning in a religious context.

celeste (Italian monolinguals):	Hue: 2.5BG–2.5PB	Value: 5–7	Chroma: 8–12
celeste (Italian-English bilinguals):	Hue: 5B–10B	Value: 6–9	Chroma: 2–10
light blue (English monolinguals):	Hue: 5B–2.5PB	Value: 6–8	Chroma: 4–10
light blue (Italian-English bilinguals):	Hue: 2.5B–5PB	Value: 6–9	Chroma: 4–10

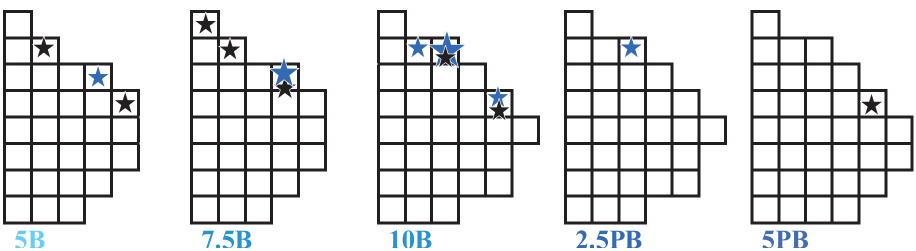

Fig. 8 – Bilinguals: Munsell charts with mapped focals of *celeste* (★) in Italian superimposed on their *light blue* focals (★) in English. The size of the symbols indicates relative number of participants' choices.

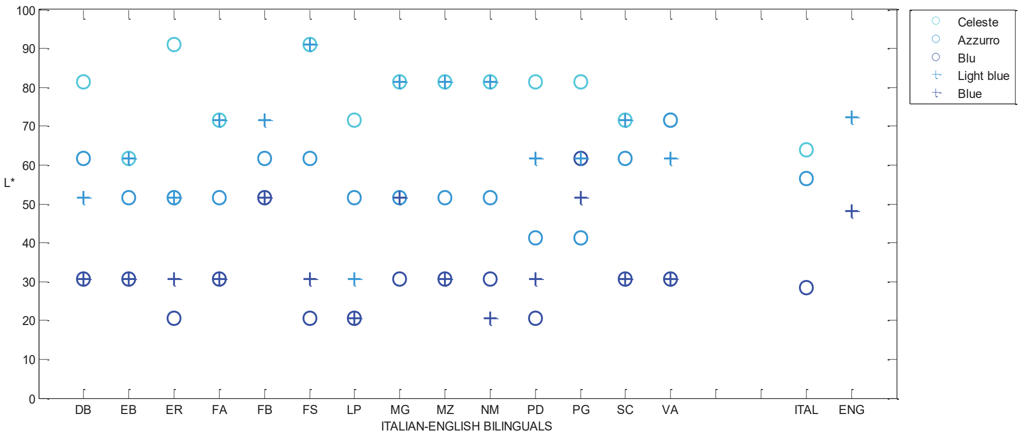

Fig. 9 – L*-coordinates (CIELAB colour space) of focal colours for individual Italian-English bilinguals. For comparison on the right, L*-coordinates of centroids of focal colours for Italian monolinguals (Alghero) and English monolinguals are shown.

3.2.4. Centroids of focal colours

Figure 9 shows *L**-coordinates (lightness; in CIELAB colour space) of focal colours of the 'blue' terms, both in Italian and English, for individual Italian-English bilinguals. For comparison on the right, *L**-coordinates of centroids of focal colours for Italian monolinguals and English monolinguals are shown. It is obvious that for the majority of bilinguals, English *blue* is understood as the same or even darker (NM) than Italian *blu*. Three proficient bilinguals (FB, MG, PG) offered though *blue* focals similar to those of English monolinguals. With regards to lightness, *azzurro* focals are similar to English monolinguals' *blue*, while *celeste* focals, though highly variable, are comparable to their and English monolinguals' *light blue*.

Table 3 presents CIELAB coordinates of centroids of focal colours by the Italian-English bilinguals. This confirms that bilinguals meaning of *blue* is definitely darker than that of English monolinguals (*L**=47.21; *a**=2.07, *b**=-49.30; Table 2). Note though that the centroids do not reflect the great variability of bilinguals' focal choices, the variability that results from significant variation in bilinguals' English proficiency, age of L2 acquisition and duration of immersion in L2-speaking environment.

Bilinguals	Colour term	*L**	*a**	*b**
Italian	*Celeste*	78.33	-8.21	-25.27
	Azzurro	54.42	-4.82	-47.26
	Blu	31.54	4.14	-42.55
English	*Light blue*	66.47	-10.51	-33.10
	Blue	33.77	-1.00	-42.26

Tab. 3 – CIELAB coordinates of the centroids of focal colours for 'blue' for Italian-English bilinguals

4. Discussion

In accord with previous linguistic and psycholinguistic studies [13–19], our results confirm that Italian speakers (Alghero) require at least two colour terms to name the BLUE area, *blu* and *azzurro* (Figures 4,6), both being basic colour terms. Also, as we demonstrated earlier [17], for the Algherese, *azzurro* has the 'medium blue' meaning. For denoting light blue shades, it is complemented by *celeste*, with the range of focals similar to that for English *light blue* (Figures 5,6). *Celeste* is argued [17] to be a contender for a third 'blue' BCT for this monolingual sample exposed to Algherese Catalan dialect [12,18], allegedly influenced by the two Catalan terms for 'blue', *blau marí* 'navy blue' and *blau cel* 'sky blue' [26]. The status of *celeste* ('relative basicness' [cf. 27]) seems though to be lower than that of *blu* and *azzurro*.

The Italian-English bilinguals reveal several features of the 'blue' focal choices diverging from performance of the Italian monolinguals (see Figures 7–9):

- When naming colour in Italian, the majority of bilinguals chose *blu* focals with Value 2 or 3, i.e. comparable in lightness to that of the majority of Italian monolinguals, thus indicating the term's 'dark blue' meaning [cf. 13–17]:

blu (Italian monolinguals): Hue: 5B–5PB Value: 2–3 Chroma: 4–12
blu (Italian-English bilinguals): Hue: 10B–5PB Value: 2–3 Chroma: 8–12.

- Noteworthy, two advanced bilinguals (FB, PG) chose *blu* focals with Value 5 or 6, indicating an adjustment of their L1 *blu* concept to that of the L2 *blue*, as in English monolinguals' *blue*.
- Further, *azzurro* focals, in Hue, fall onto the 10B, 'vivid' blue/azure, for seven bilinguals, as is the case for the Italian monolinguals (see Figures 4 and 7):

azzurro (Italian monolinguals): Hue: 7.5B–10B Value: 4–7 Chroma: 8–12
azzurro (Italian-English bilinguals): Hue: 5B–10B Value: 5–6 Chroma: 8–12.

- However, six other, advanced bilinguals chose, as best exemplar of *azzurro*, 2PB, with Values 5–7 (DB, EB, FA, VA), or 5PB 4/12 (PD, PG), i.e. blue with a purplish tint, the hues of focal *blue* for English monolinguals in the present and earlier studies [23–25]. The slight shift towards purplish is also reflected in the CIELAB a^*-coordinate: a^*=-4.82 (bilinguals) vs. a^*=-10.65, i.e. "greener" (monolinguals). This hue shift hints at the adjustment of the term meaning to the L2 *blue* concept.
- Remarkably, when naming in English, nine bilinguals indicated *blue* focals with Value 2–3, i.e. darker than those chosen by English monolinguals (cf. [23-25]), and, with regards to lightness, synonymous with their L1 *blu* (Figure 9; Table 3). Also the Hue range of bilinguals' *blue* focals is extended to 10B and 7.5B, 'vivid' blue/ azure, i.e. Hue typical of *azzurro* focals in Italian monolinguals, rather than purplish blue of English monolinguals, 2.5PB or 5PB:

blue (English monolinguals): Hue: 10B–5PB Value: 4–5 Chroma: 8–12
blue (Italian-English bilinguals): Hue: 7.5B–5PB Value: 2–3 Chroma: 6–12.

- Notably, choices of *blue* focals with Value 5, i.e. lightness for English monolinguals, were offered by three advanced bilinguals, two of whom are early bilinguals residing in the UK for 38 years (PG) or 25 years (her son MG), but in Hue the focal choices of the latter were 'vivid' blue/azure 10B.

Our finding, for the majority of Italian-English bilinguals, of the semantic shift of their L2 *blue* foci towards their L1 *blu* 'dark blue' foci along the lightness dimension is at odds with the findings for advanced Greek-English bilinguals who demonstrated lightness shift of *ble* 'dark blue' foci towards *blue* focus of English monolinguals [7].

We conjecture that the *blue*-towards-*blu* semantic shift observed in Italian-English bilinguals is effected by orthographic and phonological similarity of the Italian *blu* and English *blue* [cf. 28,29], both having identical vowel ['u'], unlike non-homophones *blue* and Greek *ble*. The orthographic-phonological similarity in the *blu*-vs.-*blue* in the present case apparently facilitates asymmetric connections between L1 and L2 in bilingual memory: The L1 is hypothesised to have privileged access to meaning (concept mediation), whereas the L2 is thought to be more likely to require mediation via the L1 translation equivalent [30].

Notably, the opposite, *blu*-towards-*blue*, shift was observed in two proficient early bilinguals, both also with very long UK acculturation, this observation according with the finding that the asymmetry is not manifested after bilinguals have acquired sufficient skill in the L2 to access word meaning directly [30].

Unlike Greek *ghalazio* 'light blue', for Italian-English bilinguals no lightness shifts of *azzurro* and/or *celeste* away from of the *blue* focal is observed. However, in proficient bilinguals the concept of their L1 *azzurro* reveals the hue shift towards that of English monolinguals' *blue*, from azure to blue with a purplish hint.

The present findings point out to Whorfian (modulation) effects in bilinguals' 'blue' naming contingent on the level of English (L2) proficiency and duration of immersion in L2-speaking environment. Specifically, they imply that Italian-English bilinguals, compared to L2 monolingual speakers, employ a 'darker' cognitive representation of the term *blue* in their L2 communication and comprehension. Conversely, in the native language their *azzurro* concept is slightly 'more purplish' than that of L1 monolingual speakers.

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5. COLOUR AND RESTORATION.
COLOUR AND BUILT ENVIRONMENT

A hyperspectral imager based on a Fabry-Perot interferometer as a tool in cultural heritage studies

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1. Introduction

In the field of cultural heritage, the knowledge of the artwork's constitutive materials is about to become essential, since it can reveal precious additional information about history, provenience and conservative condition of the object, sometimes affecting consequently its economic value too. In particular, when the artwork requires a restoration intervention, the identification and the discrimination between original and superimposed materials can be crucial for addressing the intervention itself. Moreover, as any artwork is a unique piece, the use of noninvasive techniques for studying pictorial materials is always preferred, considering that the sample taking is inevitably an irreversible operation.

Actually, it is possible to collect many data by making artwork surface interact with radiation, in a completely noninvasive manner. The obtained *spectral* information is often adequate for pigments characterization as, in the spectra, peaks, shoulders or absorption bands can help to identify pigments [1], and it can be improved extending the wavelength range used (i.e. from the Visible to the very near Infrared radiation range). Then, the comparison with standard references' reflectance spectra can aid the identification [2] but the diagnostic result's reliability actually increases by integrating investigation with other diagnostic techniques, such as X-ray fluorescence and Raman Spectroscopy.

Fiber optic reflectance spectroscopy (FORS) is a well-accepted technique for acquiring the painting's spectral information point-by-point [3, 4, 5, 6, 7].

Recently, hyperspectral imaging techniques (HSI) also are making inroads as diagnostic tools [8, 9]: they combine the painting's image with the spectral information of each pixel, with evident advantages if compared to punctual analyses. As well as being a helpful tool for studying pigments, hyperspectral imaging generates an accurate digital record for art conservation [10] and useful for monitor chromatic variation or for colour rendering elaboration [11].

Classical hyperspectral devices make use of a dispersive element and of an imaging system and they analyze the focal plane line by line, thus needing some sort of scanning system to obtain a complete hyperspectral image [12, 13, 14, 15].

The hyperspectral device here discussed [16] is an innovative apparatus that does not need any mechanical scanning system, a prototype based on a Fabry-Perot interferometer made by the National Institute of Metrological Research of Turin. At Centro Conservazione e Restauro "*La Venaria Reale*", we used this prototype for studying a small (34 cm x 49 cm) Flemish painting on copper, whose authorial attribution is still uncertain (figure 1).

The crowded and analytic composition made of brilliant colours and very subtle brushes typical of the Flemish School – the same characteristics that lead the viewer to dwell on any one detail – has represented the occasion not only for getting information useful for pigments' identification, by also for evaluating the spatial resolution performance of the instrument. For validating the HSI instrument as diagnostic tool, we selected some interesting points and we used FORS analyses as comparison means. At the end, we used hyperspectral data to calculate the RGB image, useful as basis for color rendering elaboration.

2. Experimental and method

The HSI device we used is based on a Fabry-Perot (F-P) interferometer and it measures the spectral content of each pixel of the image at the same time. This is obtained by acquiring the sequence of interference images while the optical path between the F-P mirrors is scanned by means of piezo actuators. The spectral information is finally stored in a dataset called 'hyperspectral cube': a 3D matrix formed by a 2D image and along the third dimension the spectral composition of each pixel is recorded. The technique does not need any mechanical scanning system, it is implemented in a compact set-up and it requires shorter exposure times when compared to classical methods, that could reach fractions of the second for scenes with high luminosity and with low resolution spectra [17].

This F-P interferometer could be inserted in an existing optical set-up, like a telescope or a microscope, allowing therefore the generation of a hyperspectral image of any scene of interest that could be acquired by an imaging system.

From the recorded video, acquired during the mirror scanning, it is possible to extract an interferogram for each pixel and from this the spectrum, using an algorithm based on the Fourier transform. The CCD pixel dimensions limit the final spatial resolution. The final spectral resolution is related to the maximal distance between the mirrors *L*. In frequency, the spectral resolution $\Delta\nu$ is

$$\Delta\nu = \frac{c}{2L}$$

where *c* is the speed of light.

Fig. 1 Picture of the set during a hyperspectral video acquisition.

In our prototype the spectral resolution could reach 5 THz for a scanning length of 30 μm and the spatial resolution is about 100 μm corresponding to about 250 ppi.
The use of apodization functions applied to the acquired interferogram gives a compromise between the spectral resolution and the smoothing of artefacts present in the spectra, like sidelobes [18]. The calculated spectra have to be corrected for the spectral responsivity of the CCD, for the transmittance of the optical components and the most accurate way to obtain an accurate spectrum is to add a reference white to the scene. In this application, the system can measure spectra in two bands, from 400 nm to 720 nm, and from 600 nm to 1000 nm. The spectra can then be composed in a single band from 400 nm to 1000 nm.
The hyperspectral investigation concerned three different details of the painting and we acquired videos including a white reference (*Spectralon* © 99%) within the scene: detail 1 is the main central scene, displaying Mosè dividing the waters of the Red Sea (figure 2), details 2 and 3 are two lateral scenes crowded of people, one portrayed in the background (figure 3) and so characterized by very small brushes, and one in the foreground (figure 4). The dimensions of the acquired areas are about 10 cm x 10 cm, corresponding to an image size of about 1000 pixels x 1000 pixels, due to the aperture of our F-P interferometer (for acquiring scenes with different spatial resolution we could adapt the optical system). The choice of different scenes stayed on the aim of working with areas of paint or with brushes of different sizes, therefore trying to analyse also very small paintbrushes.
All videos took 180 seconds, with a 10 THz resolution: the painting was 120 cm distant from the camera and one halogen lamp lighted the scene at 45° angle on the right to the painting, in order to reproduce one of the illuminating/viewing geometry (45°x/0°) recommended by CIE [19] and the same geometry and illumination used for FORS analyses.

Fig. 2 – Area of the painting (DETAIL n.1) of 10 cm x 10 cm acquired by the hyperspectral imager; numbers on picture refer to the FORS analyses' measurement points.

Fig. 3– Area of the painting (DETAIL n.2) of 10 cm x 10 cm acquired by the hyperspectral imager; numbers on picture refer to the FORS analyses' measurement points.

Fig. 4– Area of the painting (DETAIL n.3) of 10 cm x 10 cm acquired by by the hyperspectral imager; numbers on picture refer to the FORS analyses' measurement points.

Once we collected the three videos, we used hyperspectral data to extract *reflectance* spectra in correspondence of many figures and various interesting regions, attempting to select as most as possible homogenous coloured areas. Here we report just some significant points of the artwork that is blue, green, yellow, orange, red and purple areas of paint or paintbrushes (see table 1): areas (called *p1*, *p2*, etc.) are from 20 to 279 pixel. The minimum area corresponds to a paintbrush that is about 0.4 mm wide and 0.5 mm high, as discussed above. The operator can choose the area from which to extract spectra: pixels are numbered by the software that extracts the interferograms and calculates the spectra.

On the same selected areas (*p1*, *p2*, etc.), we performed FORS analyses by using an Ocean Optics HR2000+ES spectrophotometer and an Ocean Optics HL2000 halogen lamp, bounded by optical fibres of 400 μm in diameter. By using also a probe, we worked in a 45°x/0° geometry following the CIE standard illuminating/viewing geometry [19] and measuring area of fixed dimensions (approximately 3 mm in diameter). For the analyses we used the same *Spectralon* © 99% white reference used for the HSI videos. Collected spectra are along a 350 nm to 1000 nm wavelength range with a 0.5 step resolution.

In order to testing the use of Fabry-Perot hyperspectral device as diagnostic tool, we then compared spectra collected by FORS to the ones extracted and calculated from the HSI videos.

Table 1. Description of the areas of paint selected in the details of figures 2, 3 and 4.

AREA OF PAINT	IMAGE COORDINATES		AREA SIZE	AREA SIZE
	X	Y	[pixel]	[mm x mm]
DETAIL n.1				
Red (p1)	325-335	775-790	176	1.1 x 1.6
Blue (p2)	122-130	990-1020	279	0.9 x 3.1
Yellow (p10)	574-580	999-1006	56	0.7 x 0.8
DETAIL n.2				
Red (p32)	1131-1139	715-719	45	0.9 x 0.5
Purple (p34)	1245-1249	835-870	180	0.5 x 3.6
Green (p35)	1065-1080	588-591	64	1.6 x 0.4
DETAIL n.3				
Orange (p8)	317-321	288-297	50	0.5 x 1
Red (p21)	294-301	406-415	80	0.8 x 1
Green (p24)	156-160	314-318	25	0.5 x 0.5
Graysh blue (p26)	258-264	94-103	70	0.7 x 1
Blue (p27)	244-248	385-388	20	0.5 x 0.4

3. Results

By comparing FORS spectra with the ones calculated from the HSI videos we obtained encouraging outcomes.

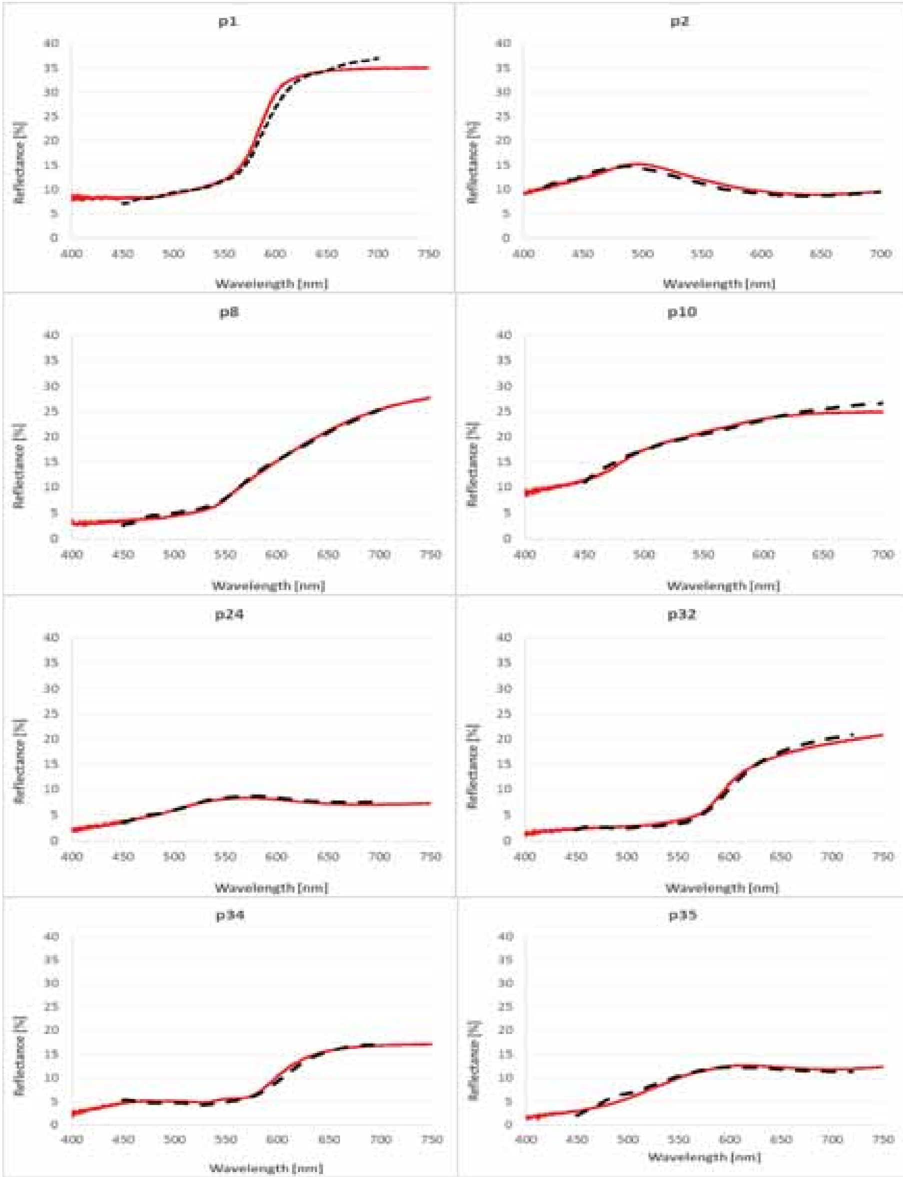

Fig. 5 – Spectral reflectance factor of the areas *p1, p2,* etc. acquired by FORS (red curves) compared to the ones calculated from the hyperspectral videos (black curves).

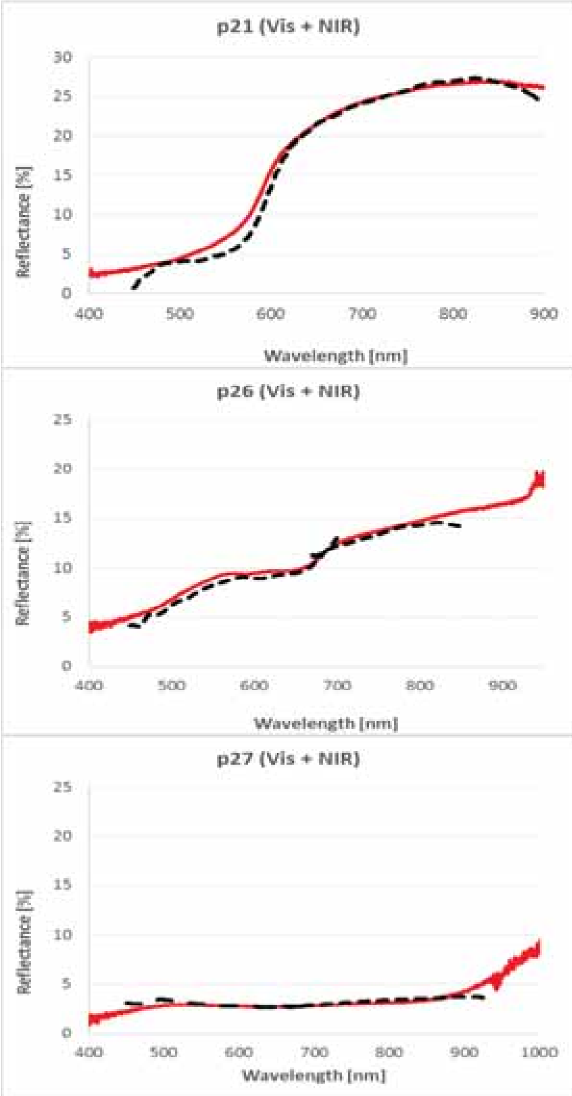

Fig. 6 – Spectral reflectance factor of the red *p21*, the grayish blue *p26* and the blue *p27* acquired by FORS (red curves, cut between 400 to 950 nm), compared to the spectra extracted from the hyperspectral videos in the visible and near infrared bands (black curves).

By a diagnostic point of view, HSI curves show all the surfaces' spectral characteristics revealed by FORS analyses in the visible wavelength range, usable for pigment identification.

For instance, both spectra report the flex at around 585 nm of the red cinnabar detected in *p1* and *p32* (fig. 5).

The double absorption band at around 530 and 560 nm is recognizable in purple *p34* suggesting the presence of a red lake probably made from cochineal [20, 21].

As shown in figures 5 and 6, spectra are comparable even in the very near infrared region (from 750 nm to 950 nm) so the diagnostic features are recognizable by both FORS and HSI technique.
For instance, spectra of the red area *p21* showed the flex at around 600 nm and the same high reflectance of the infrared radiation.
In the blue *p26*, the double absorption band at around 595 and 650 nm could be related to the presence of the smalt pigment, with the expected intermediate reflectance values in the IR region [22, 23].
In the blue *p27*, on the contrary, FORS and HSI curves showed the large absorption band centered at around 650 nm and the low reflectance values in the IR region useful for identifying azurite pigment. In particular, this was the most successful result by the point of view of the spatial resolution performance because the HSI spectrum comes from a just 20-pixel area.
At the end, since the general spectral behavior of FORS and HSI curves are comparable, also the RGB image calculation shows a good performance (fig. 7). To present a possible application of this hyperspectral technique we calculated, starting from the hyperspectral data, the RGB image of the painting details weighing each spectrum with the CIE1964 colour matching functions rendered with the D65 standard illuminant which has the maximum colour rendering index for this kind of observer [24]. This RGB reconstruction was not characterized by a colorimetric point of view (since spectra start from 450 nm) but it is intended to show the capability of the system only.

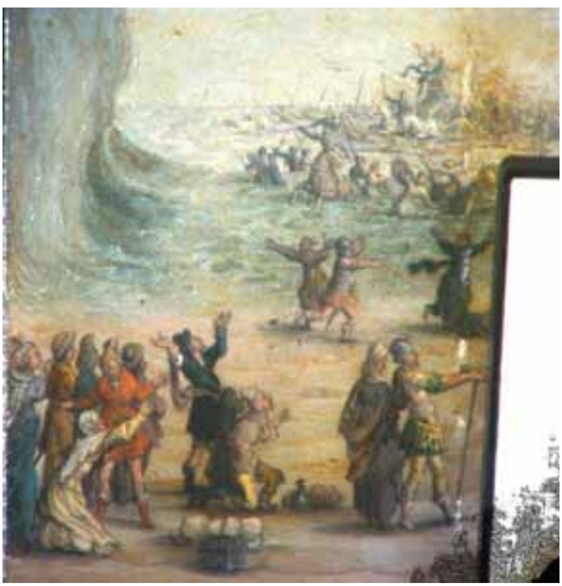

Fig. 7 – RGB image of DETAIL 2 (10 cm x 10 cm) calculated from hyperspectral data.

4. Conclusions

Figures involved in the field of cultural heritage share the importance of getting information about the artwork's constitutive materials: for this aim, the use of noninvasive techniques, such as multispectral imaging or XRF, FORS and Raman spectroscopy, is always preferred. Sometimes, that inevitably requires time-consuming and expensive operations and study.

The hyperspectral imaging techniques have in general a good advantage with respect to punctual analyses, since they can reach, or getting close, their spectral resolution performance. So their application can be thought as a tool for panoramic investigation, while punctual analyses as FORS can be limited to when a deepening is required.

The hyperspectral device here presented, based on a Fabry-Perot interferometer, shows a further advantage that is the video's acquisition speedy: the videos presented in this paper took 180 seconds only.

The availability of a fast and noninvasive tool is a precious benefit when a diagnostic campaign *in situ* is required, since many artworks cannot move from the exhibit location, because of their size or of particular guidelines.

The extension of wavelength range used, from the Visible to the very near Infrared radiation range, changing filters and laser in our hyperspectral device, allowed to getting crucial information, since some pigments such as smalt and azurite can be better discriminated for their different absorption in the infrared range.

Furthermore, the hyperspectral imaging has an advantage when the painting required an accurate study of the small details: besides Flemish School, many art movements such as Divisionism or Pointillism make use of very small paintbrushes or glazing, that can complicate the study of details. In our case, we got a good spectral information even from a paintbrush that, on the painting, is less than 1 mm wide, showing the instrument applicability as diagnostic tool.

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Color measurement procedures on 3D artworks: a case study

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1. Introduction

The color of outdoor stones is never stable in time, since they are easily attacked by atmospheric agents, thus undergoing different kinds of reactions. The degradation of stone evolves over time, and can be accelerated by the presence of different agents (chemical, physical and/or biological). In particular water, acidic substances and atmospheric particulate favor chemical degradation; the action of wind and thermal shocks facilitates mechanical disruption, while the activity of micro-organisms, algae and fungi are the basis of biological degradation [1-2].
Since the color of a stone object largely affects its aesthetic aspect, it is important to define protocols for measuring the color of the surface in a given time, in order to monitor possible color changes, and to choose the best conservation treatments, if needed. Colorimetric analysis, widely used in several applicative areas including the art conservation field, may offer an adequate solution to this problem. This method allows determination of the color parameters of an object by measuring the visible spectral reflectance of the object itself. The measurements are carried out non-invasively using portable colorimeters or spectrophotometers, supported by sophisticated software which allow a rapid and reproducible determination of the color parameters of interest .[3-10].

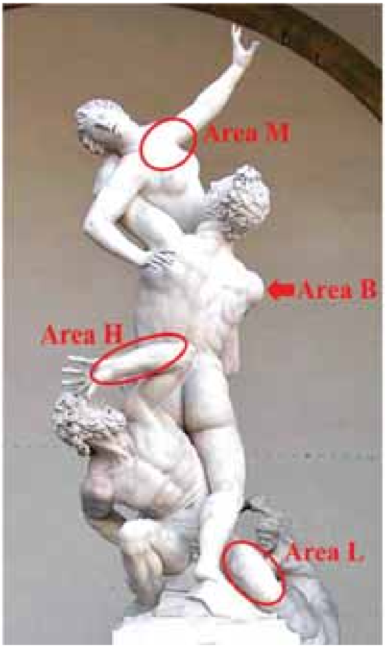


Fig. 1 - *Ratto della Sabina* by Giambologna and investigated areas

Studies dealing with colorimetric measurements aimed at documenting and supporting interventions on works of art have to be correctly programmed, since they need to be performed before, during, and after any interventions. However, one of the main drawbacks of surveys based on colorimetric analysis is connected with the repeatability and reproducibility of the measurements. This fact is of extreme importance and it is not an easy task to achieve especially when chromatic variations have to be monitored on 3D artworks, such as statues or ornamental stones.
In this paper we will report a study on color measurements performed during a biennial diagnostic survey on the *Ratto della Sabina* (1583), a marble sculpture by Giambologna, that is located outdoors, under the Loggia dei Lanzi in Piazza della Signoria, Florence (Fig. 1).

The sculpture underwent restoration in 2001. Since then, it has been constantly monitored with diagnostic surveys for the purposes of assessing its real condition and identifying the best cleaning/protective treatments. The last monitoring program took place in the years 2011-2013 and was coordinated by Magnolia Scudieri, SSPSAE of Florence, and Mauro Matteini with the technical support of the restorer Alberto Casciani. In the framework of this survey, which included several analyses (such as photographic documentation, Fourier Transform Infrared Spectroscopy, Micro-photogrammetry and water absorption measurements), the IFAC-CNR team carried out a campaign of colorimetric measurements aimed at defining the most appropriate cleaning treatment of the marble, and supporting the conservation intervention by measuring the color variations associated to the cleaning tests.
This work reports the main results of the colorimetric analyses, with focus on methodological issues that have been tackled, such as the problem of repeatability of color measurements due to the modelling of the figures, the difficult access to the areas to be investigated, and the influence of weather conditions.

2. Materials and Methods

2.1 The "Ratto della Sabina" by Giambologna

The *Ratto della Sabina* sculpture was executed by the Flemish artist Giambologna between 1579 and 1583. The statue (4.1 m in height), which is carved from a single block of marble, depicts three figures and represents a scene of the legendary abduction of the Sabines. The sculpture depicts an old Sabine man kneeling and defending himself from a younger Roman male, who stands astride him and holds a struggling Sabine woman in his strong arms. These three figures create a complex sculptural group with a dynamic spiral composition that offers multiple points of view. This artwork has always been on public display under the Loggia dei Lanzi where it was exposed, together with other important sculptures, at the behest of the Grand Duke of Tuscan in order to create an open air museum. Thus, for centuries, the statue has been at the mercy of the aggressiveness of the atmospheric agents, such as wind, rain and pollution.
The survey program encompassed the investigation and monitoring of eleven selected areas with different environmental expositions. Different analytical techniques were used in order to define the most appropriate treatment by evaluating the effectiveness of different cleaning treatments. Among these areas, the four that showed the most representative results from the point of view of colorimetric analysis were selected for this study and are described below.
<u>Area B</u>
This area was chosen on the right arm of the young Roman (Fig. 2A). It was involved in a previous treatment (in 2003) that used Wacker290 on sub-areas 1 and 2. Sub-area 3, instead, had never been treated. Five measurement points were identified as reported in figure.

Area H

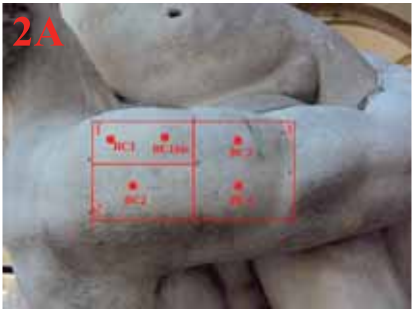
Area H was selected on the left arm of the old Sabine man in a slight rounded area strongly affected by washout. Six measurement points were identified (Fig. 2B).

Area L

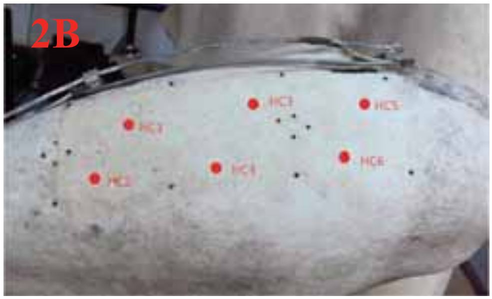
This area was chosen on a completely flat surface of the left thigh of the old Sabine. Five measurements point were identified (Fig. 2C).

Area M

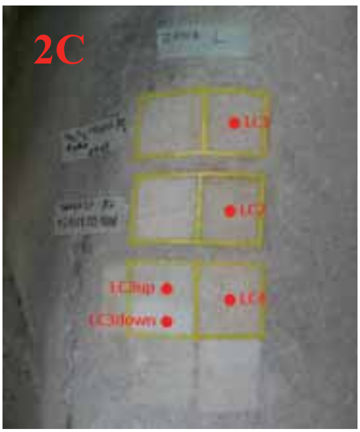
Area M was selected on the bosom of the Sabine woman in a flat area still affected by washout. Two measurement points were identified (Fig. 2D).



Area B. Sub-areas (1, 2, 3) and measurement points (BC1, BC1bis, BC2, BC3, BC4)



Area H. Measurement points (HC1, HC2, HC3, HC4, HC5, HC6)



Area L. Measurement points (LC1, LC2, LC3up and LC3down, LC4)

Area M. Measurement points (MC1,MC2)

Fig. 2 – Investigated areas

2.2 Cleaning tests

As noted, the cleaning process plays a primary role in the aesthetic recovery of artifacts, including stone ones. Indeed, due to the degradation processes, alterations and the formation of a film of dirt or incorrect restoration can transform the color of the stone over time, resulting, in the worst cases, in the loss of readability of the artwork.

Although cleaning is often a much needed operation, it is extremely delicate one. An unsuitable intervention may irreversibly damage the work by promoting the loss of material, or by making it more susceptible to degradation factors.

The cleaning treatments are usually chosen according to the nature of the stone and to its state of conservation, the type of substances to be removed and the distribution of the dirt over the surface. Depending on their nature, the cleaning procedures can be divided into chemical, mechanical or physical methods, and can be applied alone, sequentially or selectively on predetermined areas.

Chemical treatments include the use of various cleaning products (water, deionized water, organic solvents, etc.) [11-12]. Mechanical methods, instead, are based on the removal of dirt using special tools such as scalpels or micro-sandblasters, all to be used on firm stone.

Among the physical methods, the most used is the laser cleaning, which is based on the photomechanical reaction induced by the interaction between the light beam generated by a high intensity pulsed laser and the layer of dirt [13-19].

For the statue *Ratto della Sabina*, several treatments were tested in order to select the best cleaning method. Particularly, tests were carried out by using:

- Deionized water (Area B, Area H, Area L);
- Ion exchange resin (Area H, Area M): ammonium oxalate (5%) solution;
- Laser (Area L; Tab. 1).

Area L	Laser treatment
LC1	H_2O_2 (70%) 1 h (No laser)
LC2	Tween 20 (3%) + laser EOS 1000
LC3up	laser LQS (5 Hz, F_{max} 0.41 J/cm^2 on wet surface) +laser LQS@532 nm, 5Hz, F_{max} 0.2 J/cm^2 on wet surface)
L3down	laser LQS (5 Hz, F_{max} 0.41 J/cm^2 on wet surface) + laser LQS@532 nm (5Hz, F_{max} 0.6 J/cm^2 on wet surface)
LC4	laser LQS (5 Hz, F_{max} 0.6 J/cm^2 on wet surface)

Tab. 1 – Description of the laser treatments on Area L

2.3 Experimental

Measurements of the chromatic parameters were carried out with the spectrophotometer Minolta CM-2002 model. This instrument measures reflectance spectra with an acquisition step of 10 nm. Measurements were acquired using the geometry of diffuse lighting, angle of view of 8° with respect to the normal and exclusion of the specular component. The colorimetric data reported in this work were obtained as an average of five measurements and were calculated in the CIEL*a*b* 1976 color space. For each measurement, the instrument was consecutively positioned on the same spot (Ø 8 mm) on each area, and removed immediately after. Masks of reference were created in order to reposition the instrument in exactly the same point before and after the cleaning tests. Color differences were calculated, on average values, as Δ(L*a*b*) and ΔE_{76}. The color measurements were performed following the timetable reported on Table 2.

Area B / Time	Color measurements / treatments
T0 (June 9th, 2011)	On BC1, BC2, BC3, BC4 before treatments.
T1 (June 16th, 2011)	On BC1 and BC3 not treated. On BC2 and BC4 after cleaning with deionized water.
T2 (March 12th, 2012)	On BC1 and BC3 after one year of environmental exposition for comparison with BC1bis (never treated).
T3 (March 13th, 2013)	On BC1, BC3 and BC1bis after one year of environmental exposition.
T4 (March 18th, 2013)	On BC1, BC3 and BC1bis after cleaning with deionized water.
Area H / Time	**Color measurements / treatments**
T0 (June 16th, 2011)	On HC1, HC2, HC3, HC4, HC5,HC6 before treatments.
T1 (June 23rd, 2011)	On HC1, HC2, HC3, HC4 after cleaning with ammonium oxalate. On HC5 and HC6 not treated.
T2 (July 13th, 2011)	On HC1, HC2, HC3, HC4, HC5, HC6 to evaluate the repeatability of the measurements.
T3 (March 12th, 2012)	On HC1, HC2, HC5, HC6 after 8 months of environmental exposition. On HC3 and HC4 after cleaning with deionized water.
T4 (March 19th, 2012)	On HC1, HC2, HC5, HC6 for check. On HC3 and HC4 after cleaning with ammonium oxalate.
T5 (March 13th, 2013)	On HC1, HC2, HC3, HC4, HC5, HC6 after one year of environmental exposition.
Area L/ Time	**Color measurements / treatments**
T0 (July 13th, 2011)	On LC1, LC2, LC3up and LC3 down, LC4 before treatments.
T1 (July 13th, 2011)	On LC1, LC2, LC3up and LC3 down, LC4 after the laser cleaning.
T2 (March 12th, 2012)	On LC1, LC2, LC3up and LC3 down, LC4 after eight months of environmental exposition.
T3 (March 13th, 2013)	On LC1, LC2, LC3up and LC3 down, LC4 after one year of environmental exposition.
Area M/ Time	**Color measurements / treatments**
T0 (March 12th, 2012)	On MC1 and MC2 before treatments.
T1 (March 19th, 2012)	On MC1 after cleaning with ammonium oxalate. On MC2 not treated.
T2 (March 13th, 2013)	On MC1 and MC2 after one year of environmental exposition.

Tab. 2 – Timetable of the colorimetric survey on the selected areas

3. Results and Discussion

Measurements of the chromatic parameters were carried out, in time, on the same areas of the surface of the sculpture in order to point out the chromatic alterations and support curators and conservators in choosing the best conservation treatments. The main drawback that first appeared in the colorimetric survey was connected to the difficulty in guaranteeing the repeatability of the measurement, namely the possibility of reproducing the same measurement conditions in time. In order to create appropriate repeatability conditions, masks of reference were made with paper sheets previously perforated and delimited.

These masks were placed between the surface of the statue and the colorimeter in order to perform measurements without any direct contact with the sculpture and to provide some reference points for repeating the measurements in the same areas in time. In spite of this expedient, the rounded shape of certain surfaces of the statue (e.g. the arms) made it sometimes difficult to correctly re-position the instrument

The climatic conditions also influenced the measurements: the abundant rain in the days prior to the diagnostic survey (on March 2013) and the intense humidity strongly influenced the state of the marble surface. This resulted in very wet surfaces, despite an attempt to cover the sculpture with cellophane sheets during the rain and to dry the areas of interest using a hair-dryer. The surface moisture of the

marble invalidated the colorimetric measurements, particularly as regards the variations in the L* parameter, which, as demonstrated by tests reproduced in the laboratory on specimens of marble wet, presented on the wet surfaces values lower than those recorded on the dry ones.
Below, the results of the color survey for each area are reported.

Area B

Before the cleaning intervention, sub-areas 1 and 2 treated with Wacker290 in 2003 (BC1, BC2) appeared clearer and more yellowish as compared to those never treated (BC3, BC4). After the cleaning treatment with demineralized water on BC2 and BC4, an increase of the lightness occurred in both areas, while a decrease in the yellow component was observed in the pre-treated one. However, no significant color changes were recorded in the two uncleaned points (Tab. 3).
It must be kept in mind that the surface of this area was exposed to washout but in a uniformly way. The right portion of the treated sub-area was not exposed to rain than the left one. This inhomogeneous exposure to water prevented an objective interpretation of the data. Based on this fact, one year later the first survey, it was decided to choose a new measurement point, named BC1bis, located in a less exposed point of the treated sub-area 1, to obtain a more reliable comparison with the untreated subarea on the right (BC3). Furthermore, considering the difficulties in repositioning the instrument on the BC2 and BC4 points (due to the rounded modelling of the arm), these points were not considered in the following measurements surveys.
After one more year, the color variations recorded were very modest with a slight decrease in the L* parameter, perhaps due to the deposit of fine particulate. After a slight cleaning with deionized water a recovering of lightness occurred that was more pronounced on the BC1 point.

Area	L*					a*					b*				
	T0	T1	T2	T3	T4	T0	T1	T2	T3	T4	T0	T1	T2	T3	T4
BC1	83.2	83.2	83.5	78.1	81.3	0.7	0.7	0.5	0.6	0.6	10.5	11.1	10.2	9.3	10.0
BC2	79.3	83.9	---	---	---	0.8	0.4	---	---	---	10.9	9.9	---	---	---
BC3	75.5	76.1	74.5	72.2	74.0	0.5	0.6	0.7	0.7	0.8	7.3	7.7	8.1	7.2	8.0
BC4	70.8	80.2	---	---	---	0.8	0.6	---	---	---	8.3	8.6	---	---	---
BC1 bis	---	---	73.6	72.1	72.3	---	---	0.8	0.7	0.8	---	---	9.3	8.3	8.9

Tab. 3 – Area B. Averaged colorimetric values (L*, a*, b*) for each measurement point before (T0) and during the diagnostic survey.

Area H

Color measurements performed after a treatment with ammonium oxalate (T1) showed, in the treated points (HC1, HC2, HC3, HC4,), a slight general tendency to yellowing (not visible to the naked eye) and a decrease in lightness (except for HC3; Tab. 4).

Area	L*						a*						b*					
	T0	T1	T2	T3	T4	T5	T0	T1	T2	T3	T4	T5	T0	T1	T2	T3	T4	T5
HC1	79.9	78.7	79.3	73.3	75.8	68.9	1.2	1.6	1.6	1.6	1.5	1.7	11.7	12.2	12.2	12.3	12.2	11.0
HC2	81.9	79.7	79.9	76.2	75.0	76.0	1.2	1.9	2.0	1.9	1.9	1.9	12.4	13.6	13.2	14.3	13.8	12.6
HC3	80.7	82.3	82.1	80.3	79.3	72.8	0.2	0.6	0.6	0.6	0.6	0.9	9.1	10.0	10.0	9.7	9.9	9.8
HC4	82.1	80.8	80.8	81.1	79.7	75.6	0.6	0.9	1.0	0.8	0.9	1.0	9.8	10.8	10.7	10.2	10.5	9.8
HC5	81.3	81.2	81.5	73.7	74.7	71.2	0.3	0.3	0.3	0.7	0.7	0.6	9.1	9.6	9.7	9.0	8.7	9.0
HC6	82.9	81.6	80.7	76.1	76.4	74.5	0.3	0.5	0.3	0.7	0.8	0.7	9.1	9.8	9.8	10.0	10.4	9.0

Tab. 4 – Area H. Averaged colorimetric values (L*, a*, b*) for each measurement point before and during the diagnostic survey.

However, since the rounded modelling of this area made it difficult to carry out the measurements, it was decided to repeat again the analysis after ten days (T2) in order to validate the repeatability of the procedure and the reliability of the acquired data. The values obtained were completely congruent with the previous ones ($\Delta E_{T1-T0}=\Delta E_{T2-T0}$ except for HC6; Tab. 5).

D65/10° Area di misura	ΔE (T1-T0)	ΔE (T2-T0)	ΔE (T3-T0)	ΔE (T4-T0)	ΔE (T5-T0)	ΔE (T6-T0)
HC1	1.3	1.3	1.9	1.3	4.7	6.5
HC2	2.0	2.0	2.4	2.9	6.8	8.6
HC3	2.0	2.0	1.5	2.0	5.1	7.5
HC4	1.7	1.7	1.2	2.5	6.5	8.8
HC5	0.7	0.8	7.6	6.6	10.1	10.3
HC6	1.5	2.3	6.9	6.7	8.4	10.4

Tab. 5 – Area H. ΔE_{76} color differences before and during the diagnostic survey

The control measurements carried out on HC1, HC2, HC5 and HC6, after 8 months of environmental exposure (T3), showed a general tendency to turn gray. Instead the L* values measured in the HC3 and HC4 points, cleaned with demineralized water, resulted to be the same L* values of 2011 ($\Delta L^*_{T3\text{-}T0}$<1), probably thanks to the cleaning intervention to which they were subjected. A treatment with ammonium oxalate, on the same points, induced a slight graying of the surface ($\Delta L^*\approx 2$).

Area L

When the measurements performed before (T0) and after the selected cleaning treatments (T1) were compared, it was found that all treatments induced a significant increase in the lightness of each point (ΔE>7), due to a reduction in the graying of the surface (Tab. 6).

Area	ΔE (T1-T0)	ΔE (T2-T0)	ΔE (T3-T0)	ΔE (T4-T0)
LC1	7.6	9.0	7.7	4.8
LC2	8.9	12.1	9.7	4.9
LC3up	10.0	7.3	4.1	1.7
LC3down	16.2	12.9	8.5	4.9
LC4	7.8	6.0	3.0	2.5

Tab. 6 – Area L.ΔE_{76} color differences before and during the diagnostic survey

Furthermore, an increase in the b* coordinate, corresponding to an increase of the yellowness of the surface, was registered in all points with the exception of LC3down, where the maximum clearing up was also calculated ($\Delta L^*\approx 16$).

After 8 months (T2), the major color changes were recorded on LC2 and LC3down, the least on LC4. In particular, the slight yellow tone that the different subareas showed after laser cleaning, regressed in all areas, and mostly in LC2 ($\Delta b^*_{T2\text{-}T1}$=-2.4). Furthermore, the three sub-areas (LC3up, LC3down and LC4) treated with the LQS laser, underwent a decrease in lightness, reasonably attributable to a graying caused by a deposit of particulate. For the two sub-areas treated with hydrogen peroxide (LC1) and Tween 20 + Laser EOS1000 (LC2), instead, an unexplained increase in lightness was found (Tab. 7).

Area	L*				a*				b*			
	T0	T1	T2	T3	T0	T1	T2	T3	T0	T1	T2	T3
LC1	68.3	75.0	76.7	75.7	2.0	2.9	2.2	2.2	10.9	14.2	13.8	12.7
LC2	68.6	76.8	80.6	78.3	1.6	2.0	1.0	1.1	10.5	13.7	11.3	10.5
LC3 up	69.5	79.3	76.6	73.4	1.7	0.2	0.4	0.5	10.9	12.1	11.3	10.6
LC3 down	69.5	85.5	82.1	77.4	1.7	-0.7	-0.3	-0.1	10.9	10.0	9.1	8.5
LC4	73.8	80.5	79.3	76.7	0.9	0.8	0.6	0.5	9.5	13.4	12.0	10.3

Tab.7 – Area L. Averaged colorimetric values (L*, a*, b*) for each measurement point before and during the diagnostic survey.

Area M

Area M was added in 2012 in order to carry out a further treatment with ammonium oxalate (in addition to that one already performed on Area H) on a flat surface of the sculpture, which was exposed to corrosion and easily accessible by instrumentation. Two subareas were here identified: the left part (MC1) was treated with ammonium oxalate, the right one (MC2) was not.

Although the cleaning treatment was applied only on MC1, the colorimetric analysis showed similar chromatic variations in both points (Tab. 8-9). The most reasonable explanation for this unexpected result is that, during the intervention, the ammonium oxalate solution applied on MC1 had spread in the contiguous MC2 point causing this outcome.

Area	L*			a*			b*		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
MC1	82.7	77.9	77.5	0.2	1.0	1.1	9.8	10.7	9.9
MC2	82.1	77.0	81.0	0.3	1.0	0.8	10.5	10.8	10.1

Tab. 8 – Area M. Averaged colorimetric values (L*, a*, b*) for each measurement point before and during the diagnostic survey.

Area	ΔL* (T1-T0)	Δa* (T1-T0)	Δb* (T1-T0)	ΔE* (T1-T0)
MC1	-4,84	0,8	0,9	5,0
MC2	-5,10	0,6	0,3	5,1

Tab. 9 – Area M. ΔL*,Δa*, Δb* and ΔE_{ab} color differences T0 – before cleaning test, T1 – after cleaning test on MC1

5. Conclusion

This work illustrates selected results of the colorimetric measurements campaign carried out in the framework of a wider survey performed on the sculptural group *Ratto della Sabina*, located in Piazza della Signoria in Florence. The importance of this artwork, together with the special complexity of the modeling of this statue, makes this case study representative of the peculiar questions related to the use of colorimetry to monitor the degradation of outdoors 3D artworks.

In the analyzed case, the obtained data showed the extreme importance of defining a protocol to ensure repeatability of measurements over long time periods. Among the factors to be considered, the role of the atmospheric conditions, which introduce a further source of variability, since may temporarily affect the color surface, has to be taken into account. The comparability of data acquired on the same areas at different times is the essential ingredient to guarantee the reliability of data. For these reasons, during the long term campaign carried out on the *Ratto della Sabina*, some of the data acquired had to be discarded. However the remaining data could be used to evaluate the effectiveness of the cleaning procedures and were used as support in the choice of the best conservation treatments. In particular, the best results were reached by means of laser cleaning (with an evident increase of the lightness), although in some cases laser induced a yellowing of the surface (increase of the b* parameter). Moreover, color measurements performed few months after cleaning (with every kind of treatments) showed a tendency to darkening of the stone (decrease of L* parameter). This tendency was maybe due to the sedimentation of dust and atmospheric particulate on the surface, especially on the areas not subjected to washout.

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Is it easy being green today?

Green colour application in architecture and built environment

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1. Introduction

The main goal of this article is to explore the multifaceted significance of the green colour in the built environment, including its history, traditions and contemporary application.

In almost all regions of the world the formation of the separate word for green occurred in the later language development. According to Berlin and Kay [1969], the name of the green colour appears when there are already existed white, black, red and yellow colour-words. In Slavic languages the name of the green colour (e.g. Polish *zielony* or Russian *зеленый*), comes from the words: *zioło* or *ziele* (means herb). English *green* (Old English *growan*, Anglo-Saxon *grene*), the German *grün* or Dutch *groen,* evolved from the old Germanic (Teutonic) *grö* meaning "to grow" [Ryan 2012, Schindler 2008]. The Old Chinese character 青(*qīng*), referred both to green and blue[1], depicts the budding of a young plant and can be understood as "verdant"[2]. With regard to this green colour-word evolution, its direct connections with greenery of nature as well as plant's life are clearly visible. Not surprisingly, green's various symbolic nuances include wide range of meanings on the spectrum between growth and decay [Ryan 2012]. John Hutchings [1997] claims that: "*all common symbolic meanings are derived either from green growth that occurs in the springtime or from green mould of decay".* Surveys made in Europe and the United States confirmed that green is the colour mostly associated with nature, youth, spring and hope [Varichon 2006]. As a metonymy for nature, the colour green has been often symbolically referred to vegetation, fertility and productivity [Ryan 2012]. But green has also negative connotations with nausea, poison, illness and decomposition, as well as jealousy (e.g. "green with envy") [Lancaster 1996]. Green is often defined as the intermediate colour (Lat. *Color medius*) between heat and cold, fire and water, "heavenly" blue and "hell's" red. Aristotle was placing the colour green as a central colour between black (ground) and white (moisture) [Gage 2008 p.13]. Green colour is regarded to be most restful to the eye and, according to Goethe [2006], generates balance. It regenerates physically and mentally, calms and helps to recuperate. Green's colour effect depends on its shade – emerald green calms and cools, yellow-green invigorates and stimulates. Green is often treated ambivalently, depending on additive or subtractive colour mixing – in the first being primary in the second secondary colour. However, in terms of the colour understood as a representation of a visual quality, green is considered to be a primary one [Schindler 2007]. Green, mostly due to its associations with nature and environment, has become an exceptional colour. Therefore, rationale for its use in architecture were and are very diverse. Different ways of application of green in the architectural

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[1] In some ancient languages, including Old Chinese, Thai, Old Japanese, and Vietnamese, the same word could mean either blue or green [Varichon 2006].

[2] http://www.illuminantpartners.com/2011/01/17/colour/

space can be expressed by some specific categories: Green as a main "Nature's colour", Green as a camouflage colour, Green as a contrast colour, Green as a traditional and brand colour, Green as a material colour, Green as a symbol / idea, Green as modern, fashionable colour.

2. Green as a main "Nature's colour"

In this category green, as a predominant colour of plants in the chlorophyll-green area, present as an usual background for architecture in open landscape, requires special concern. Green occupies more space in the visible spectrum than the other colours. The human eye is sensitive to the infinite nuances and subtleties of green – thousands of variations on emerald, jade, lime, pine, sage, mint and olive tones. In daylight colour receptors - cones are most sensitive to yellow-green light [Lancaster 1996 p.69] with predominant wavelength in the range ~492–577 nm. Thus, the choice of a green colour for building exterior has always been a problem. For some architects **green needs to be excluded from architectural colour palette**, as too competitive and/or too hard to harmonize with the mixed greens of nature [Schindler 2007]. Luis Barragan wrote, that he never used green in his buildings, because he would not know how to do it. "*The* (painted) *green would compete with nature, so that the one or the other would perish"* [Barragan 1981]. Michael Lancaster advises that, to avoid ambiguity in the case of the buildings seen against a green background: *it is necessary to use greens that contrasts with the mixed greens of nature […] or better to follow traditional precedents and use colours that are more in contrast* [Lancaster 1996]. But for other architects, **green colour is used as a tribute to nature**, which is reflected not only in application of so called **"living" walls or roofs**, but in **artificial grass** or **green plants imitations** applied on the façades, as well.

2.1. Green living walls and roofs

Contemporary architecture very often integrates vegetation as an element of building structure in the form of the **"green roofing"** or **"green walls".** Because of the "natural" character of the used material, "*this architecture blends with surroundings, thus becoming a piece of nature itself"* [Schindler 2008]. As early as the sixth century BC in Babylonia and the Mediterranean countries, roof gardens were constructed mainly for recreational and aesthetic purposes. Later, they gained utilitarian character as a natural protective layer against both high and low temperatures as well as a fire-protection. The development of the modern green roof's constructions is associated with the new architectural philosophy initiated by Le Corbusier. Roof gardens became one of "The Five Points of a New Architecture" - a set of architectural principles defined by Le Corbusier in 1923. in *Vers une architecture* [Le Corbusier 2012]. Nowadays, the popularity of green roofs - extensive or intensive – is still growing. Among many examples of green roofs it is worth to mention over 1 hectare large roof garden of the California Academy of Sciences designed by Renzo Piano (San Francisco, 2008)[3].

The oldest way to create **green façade** is to cover it by climbers e.g. *Parthenocissus tricuspidata*, or by *Parthenocissus quinquefolia*. Both are widely grown as a

[3] http://www.archdaily.com/?p=6810

climbing ornamental plants, to cover the façades of masonry buildings. They can significantly reduce cooling costs, through shading walls during the summer, as well. One of the most famous uses of *Parthenocissus tricuspidata* is on the brick outfield walls of the Wrigley Field baseball stadium located in Chicago (US). Modern technology of the façade made from plant material called „living walls" (from French: *murs végétaux*) or „vertical gardens", was invented by the French botanist Patrick Blanc in 1988. One of his best known green walls was realized in 2005 in Musee du Quai Branly in Paris, France, designed by Jean Nouvel[4] [Schindler 2007]. Gradually the buildings covered with vertical gardens were built in whole Europe and beyond. Today "green facades" are performed in a variety of technologies, which allow soilless cultivation of plants in artificial conditions e.g. through the use of hydroponics. **Current development of the green walls and roofs is dictated mainly by environmental and economical reasons, however their aesthetical values and visual merging into the landscape are very important factors, as well.**

2.2. Artificial grass

In terms of the green colour used by architects in reference to the main colour of vegetation, one can observe growing interest in **using artificial grass for roofing or as wall finishing material.** The main advantage of this evergreen building covering is no need of water or maintenance. But the visual appearance of such greenery is completely different than the natural grass. The main distinction is the **visual invariability of the synthetic grass during changing seasons**. Amalia House by GRID Architects is one of the first buildings with artificial grass in Austria (Styria 2007). To give tribute to the nature around and to maximize the interchange between inside and outside, the house is completely covered with synthetic grass[5]. Although during spring and summer unnatural green harmonizes with its naturally verdant surroundings, in the wintertime situation is completely reverted. **During winter season – especially after snowfall - artificial green of the grass seems to be completely alien, yet invasive in the mostly white and black environment.** The same visual effect is observed in House in Laufnitzdorf by Albert Josef Ortis in Reinhold Weichlbauer (Austria 2009)[6], as well as in 2db Transformation Residential House designed by Dubail Begert Architectes in Swiss Saignelégier (2013), where the garden facade is coated with artificial turf[7]. Giant, triangular sloping roof of BTEK – Bizkaia Technology Interpretation Center by ACXT in Derio (Spain 2009)[8] is covered with artificial turf as well, emerging as an extension to the ground. Similarly, IDOM Headquarters by ACXT Arquitectos in Bilbao (Spain 2011) in addition to the green façade made of aluminium profiles, is covered by partially artificial - partially natural green roof's carpet, hiding all air conditioning units[9].

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[4] http://www.verticalgardenpatrickblanc.com/realisations/paris/quai-branly-museum
[5] http://www.archdaily.com/?p=3877
[6] http://www.a10.eu/magazine/issues/30/house_laufnitzdorf.html
[7] http://www.archdaily.com/?p=522816
[8] http://www.archdaily.com/?p=39177
[9] http://www.archdaily.com/?p=225210

2.2. Green plants imitations

Completely different visual effect is achieved by **façade decorations inspired by green plant's colour shades, shapes and forms**. In the history of architecture such inspirations can be found already in Arts and Crafts Movement (1888 – 1910), Art Noveau (1890–1910) as well as in later Art Déco (1919–1939). Distinguished façade covering in light green and brownish geometrical tiles decorates Portois & Fox Office Premises and Houses by Max Fabiani in Vienna (1900). Steel structure of the Porte Dauphine Metro Station (Metropolitain) in Paris by Hector Guimard (1901) in monochrome green functioned as corporate identity. Analogies to this aesthetics can be also found in the distinguished façades of green ceramic tiles of the iconic De Bijenkorf Department Store designed by Gio Ponti in Eindhoven (The Netherlands, 1970). **Nowadays, modern technologies allow architects to construct green facades in even more direct analogies to the vegetation**. Kindergarten Sighartstein designed by Kadawittfeldarchitektur in Sighartstein (Land Salzburg, Austria 2009)[10] is situated on the periphery of the site of green meadows and fields. This location was an inspiration to create the sculptural façade decorated by the oversized, green metal "grass blades". This stylized stalks are not only ornamental, but also act as a continuation of the landscape theme. A "green grass"-like skin, made by the reuse of wasted wood attached to a steel grid, decorated Brazilian Pavilion for World Expo 2010 in Shanghai, by Fernando Brandão Arquitetura e Design (2010). Beautiful, green artificial plants adorn the façade of the Zaluski Brother's Tenement House, designed by KAPS Architects in Warsaw (Poland 2010)[11]. In the Lounge MS by Vaillo + Irigaray in Navarra (Spain 2007)[12] façade is made of recycled plastic tubes in different colours inspired by reeds.

Due to the improvement of reproduction techniques architects are able to print preferable images directly on the building materials. Green plants representation are among the most popular, thus giving **the effect of the real vegetation on the façades**. The multi-storey car park next to the Kunstcluster Shoping Mall, designed by van Dongen-Koschuch (Nieuwegein, The Netherlands 2012), forms a "green lung" in the stone-built urban environment. Prints on the balustrades and other glazed surfaces of the garage frontage graphically reflect the bamboo image[13]. In the Le lycée technique des Arts et Métiers by Romain Hoffmann (Luxembourg 2012)[14] green Trespa Meteon Graphics panels were used, thus resulted in a stunning façade of the unique plant patterns with a random repeat.

The most distinctive way of the green plants imitation in architecture is materialized in **biomorphic structures created in organic way**. Such stylized plant's representations can be found e.g. in the works of Jakob + MacFarlane Architects in Docks de Paris - City of Fashion and Design (Paris, France 2004)[15] as well as in Jacques Ferrier's bridge - Overfly in Choisy (Choisy-le-Roi, France 2010)[16].

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[10] http://www.archdaily.com/?p=34252
[11] http://www.kaps-architekci.pl/?p=294
[12] http://www.archdaily.com/?p=20822
[13] http://www.archdaily.com/?p=383888
[14] http://www.prefalux.lu/?portfolios=lycee-des-arts-et-metiers-a-luxembourg
[15] Artist Intervention on the façade by Yann Yersalé [http://www.jakobmacfarlane.com/en/project/701/]
[16] http://www.archdaily.com/?p=80387

3. Green as a camouflage colour

This section refines problem of the desirable **invisibility of the green architecture.** The reasons for camouflaging the buildings in the natural green surroundings are various. **Green is sometimes used by architects to hide big structures e.g. magazines or industrial buildings,** as well as **some "unwanted but necessary" elements of architecture** such as silos, technical towers etc. Sometimes architects exhibit tendency to choose **green colour to hide rawness of architecture behind its "green" appearance**, since: "*Ugly Green buildings are more readily accepted than* (simply) *ugly buildings"* [Jarz 2011]. **Green often serves as the "default" colour of street noise barriers and some elements of small architecture**, as well. In case of the popular urban furniture, such as: park benches, fences, street lamps, trash cans, sign's columns etc. specific colour code is observed. Due to the fact that these objects generally should fulfill its function, without becoming the subject of special interest, their colours are designed mostly to blend with the natural green areas. Thus, for park benches and trash cans as well as low fences in parks and squares, low saturated, emerald green (~ RGB 40,84,83) or dark-green (RGB ~ 24,72,45) colours are often selected. This hues harmonize both with many shades of green present in the landscape, as well as with other surrounding colours e.g. of the pavements [Tarajko-Kowalska 2009]. Sometimes, green paint, because it is green, is commonly assumed to be suitable for buildings seen against a green background in open landscape [Lancaster 1996 p.38]. According to Berit Bergstrom [2008, p. 30] in the chlorophyll-green area, hues between G40Y and G50Y (in NCS system nomenclature) accounts for the majority of green inherent colours. Therefore, the best effect of colour merging can be achieved by using greens in this range of hues. But it is not so easy to find just one particular green tone, to harmonize with infinite nuances of the greens found in nature. Thus, architects often use many different shades of green in form of **pixelated or patchwork façades**, to achieve visual merge with the landscape's multiple greens. This effect is found e.g. in Cava & Hotel Mas Tinell in Vilafranca del Penedes, designed by Josep Lluís Juanpere and Escamis (Barcelona, Spain 2013). This 5 star hotel is remarkable not only for its peculiar shape, which resembles two rows of bottles of wine put into rhyme, but for waving mosaic roof in carefully selected low saturated greens in different lightness, as well[17]. The colour gradient of the solar-powered single family house built in Berlin by Brandt + Simon Architekten (Germany 2009), gets darker towards the ground and blends with the adjacent treetops[18]. Lago Vista House in Los Angeles has been designed by Aleks Instanbullu Architects to blend with the native grasses. This unique sculptural form was inspired by the colours of the vegetation on the steep hillside slope[19]. Being in the midst of a poplar forest, the building façade of Modsim by Yazgan Design Architecture (Ankara, Turkey 2009) forms a visual reflection of all greens of the surrounding[20].
The camouflage of the building can be also achieved by the use of **translucent green coloured glass**. This mirror effect is observed e.g. in the installation

[17] http://www.hotelmastinell.com/en/
[18] http://www.archdaily.com/?p=361349
[19] http://ai-architects.com/project_single/hillside-home-hollywood-hills-la-5/
[20] http://www.archdaily.com/?p=497978

Réflexions colourées by Hal Ingberg (Montréal, Québec), which was originally created for the 2003 edition of the International Garden Festival [Moor 2006]. Build in the midst of forest, a semi-reflective equilateral triangle provides an intimate enclosure that both intensifies and frames the perception of the surroundings[21].

4. Green as a contrast colour

Green colour can be analogous, but at the same time, completely contrasted to the hues of the natural site context. **Ideas of greenness formulated in temperate climates should be completely reverted in dry habitats.** [Ryan 2012]. In a desert climate, each tiny bit of green, either grayish, bluish or brownish, has a huge impact because of the perceptual sand dust [Doherty 2010 p.38]. This effect is achieved e.g. by architecture studio Huma in Roldan Public School and Primary (CEIP), located on the plain of Camp de Cartagena in southern Spain. The entire campus features a façade covered with green Astroturf, resembling a miniature golf course from the sky[22]. **Green buildings can be also contrasted to the nature's greens by their colour tone, intensity and/or brightness.** That is observed e.g. in Gigon / Guyer's Donation Albers-Honneger/EAC in Mouans-Sartoux (France 2004). The vivid lime green colour of the façade is startlingly alien yet, at the same time, analogous to the surrounding hues [McLachlan 2012 p. 105-106]. Also Euronews Headquarters in Lyon, called 'Green Cube', designed by Jacob + Macfarlane (France 2014) with bright green façade shaped by artist Fabrice Hyber is highly visible on its less saturated background[23]. **Green colour can be also used as a visual representation of the "empty space" contrasted with the "built surroundings".** In the collage "Ground Zero"– proposal for the World Trade Center site (2003) – artist Ellsworth Kelly was inspired by the aerial view of the area, to make a simple representation of flat green space: *"a 'visual experience', not additional buildings, a museum, a list of names or proposals for a freedom monument"* [Rouw 2010].

4.1. "Green is not Red"

This quotation of Paul Klee[24] (statement derived from Ewald Hering) is used here to describe **green as a main complementary colour to red,** forming one of the three fundamental pairs of opponent colours [Schindler 2007]. Although different origins, green colour shares with red connotation of "life" and "joy". As red symbolizes the blood of human life, green determines plant growth. Thus, for example in Hungarian tradition Red and Green symbolize duality of life [Zöldi 2010]. Combination of this two colours is very popular both in traditional and contemporary architecture. Red ceramic tiled roofs and green-painted wooden facades are typical e.g. for the Zaan region in The Netherlands. Curious modern interpretation of this tradition is found in Inntel Hotel Amsterdam-Zaandam by WAM architecten in Zaanstad[25]. Le Corbusier used this combination of two colours in Cité Frugès - Ville de Pessac, (France 1926), as well as Clotindo Testa in Campus Universidad del Salvador in Pilar (Buenos Aires 2002). Red-green colours scheme is

[21] http://www.refordgardens.com/english/festival/garden-11-reflexions-colourees.php
[22] http://inhabitat.com/beautiful-roldan-school-keeps-cool-under-a-cover-of-green/
[23] http://www.jakobmacfarlane.com/en/project/euronews-headquarters/
[24] In 1921 Paul Klee has painted "City Picture with Red and Green Accents".
[25] http://www.wam-architecten.nl/projecten/06293_Intell_Hotel_Zaandam.php?english

oftentimes present in Saurebuch-Hutton's works such as: Fire and Police Station in Berlin (Germany 2004), University of Sheffield department building - Jessop West, (Sheffield 2008) or Cologne Oval Offices in Cologne (Germany 2010)[26]. In DV Atelier (Studio House) by deffner voitländer architekten in Dachau (Germany 2005) the red surfaces, visible when the window's shutters are open, are in strong complementary contrast to the glass green shade of the façade [Linz 2009 p.106-113]. In Sarphatistraat Offices designed by Stephen Holl (Amsterdam, The Netherlands 2000) the exterior expression is one of complimentary contrast by new perforated copper structure adjacent to existing red brick's buildings[27]. Similarly, in JWS 2b residence by KBNK (Lübeck 2013) green patinated cooper spaces wrap around the house, while at the same time the ground floor "merges" with the base by using a homogeneous red brick texture[28].

5. Green as a traditional and brand colour

Firstly, this category refines problem of the different traditions connected with green colour in architecture. Secondly examples of the green used in visual identification of the brands in built environment are presented.

5.1. Green colour traditions

Green is considered the traditional colour of Islam, as the colour of Prophet's Muhammad robe and turban [Lenclos 2004 p.29]. Revered in Muslims culture for evoking the greenery of paradise [Rawsthorn 2010], green colour holds only positive meanings as: life and nature, oasis, abundance, fertility and joy. In immigrant communities the use of green colour often indicates houses of the inhabitants from Pakistan, as green is colour of Islam's flag as well as the whole nation [Lancaster 1996 p.69]. However, only inhabitants, who have made pilgrimage to Mecca are allowed to paint their houses green or turquoise tones e.g. in Ghardaia (city in Algerian Sahara in oasis complex M'zab) [Lenclos 2004 p.26]. Green colour is also often found in mosques, all over the world e.g. in the famous Al-Masjid al-Nabawī . The Prophet's Mosque, situated in the city of Medina, has been presumably built by the Muhammad himself in 622. One of the most notable features of the building is the Green Dome in the south-east corner of the mosque, where the tomb of Muhammad is traditionally located. The dome was for the first time painted green in 1837.

Green is also an emblematic colour of Ireland, which is often referred to as the "Emerald Isle". It represents both the typical vast green hillsides of the island landscape, as well as Ireland's patron Saint Patrick. According to J.P. Lenclos, many Irish houses as well as pub's entrances are painted green in honor of the patron saint [Lenclos 2004 p.29]. Each year, during St. Patrick's Day (March 17th) many buildings throughout the world are illuminate in green, as well as different rivers are dyed in this colour e.g. Chicago River, according to more than fifty-year-old tradition of the city[29].

[26] http://www.sauerbruchhutton.de/#projekte
[27] http://www.stevenholl.com/project-detail.php?id=41&worldmap=true
[28] http://www.archdaily.com/?p=512924
[29] http://www.theirishstore.com/blog/2014/02/11/22-world-famous-places-go-green/

In many kinds of traditional architecture, **green is often used for the window's shutters in contrast with the colours of the façade** [Schindler 2007]. This tradition may be connected with the 18th century belief that the arsenic in the paint may have some residual effect on insects after the paint had dried. As many popular 18th and 19th century green wallpapers and paints were made with arsenic [Rawsthorn 2010], the shutters have presumably been painted green to repel or even kill insects that come in contact with the painted surface[30]. However arsenic is not present in contemporary green colorants, the "green shutters" tradition still remains in many places throughout the world. For example in Italian island of Burano green shutters, repeated in each house, help to create visual harmony and unity between differently coloured façades. Modern reference to this tradition can be also found in Leeuw House by NU architectuuratelier in Sint-Pieters-Leeuw (Belgium 2014)[31].

5.2. Green as a brand colour

Green colour serves also as a visual identification of the brands in built environment e.g. **BP petrol stations, Starbucks coffee shops, as well as various beer concerns, such as: Heineken, Carlsberg[32], Grolsch or polish Lech.** For example all the six Carlsberg Breweries, built in India during last ten years (2007-2014), either are fully green or have some decorative elements performed in green e.g. The Alwar Brewery in Alwar, Rajasthan (2008) or The Hyderabad Brewery in Andhra Pradesh (2010)[33]. New bottling plant added to Northampton brewery is executed in green colour, as well (2013). Heineken Experience is located in the former brewery in Amsterdam (The Netherlands 1991), offering many attractions for concern's fans. The entrance zone, as well as the details inside are performed in green hue, typical for concern's products. Similarly, green coloured façade adorns Heineken House Mexico by Art Arquitectos, located in Ciudad de México (México 2011)[34]. Green distinguishes also the BP (British Petroleum) petrol stations, throughout the world. Although, the colour green is central to the BP brand since the 1930s, the company has lost its attempt to register a trademark for the colour Pantone shade 348c [Safi 2014][35].

6. Green as a material colour

Nowadays green buildings are realized in wide range of the materials such as coloured glass, metal cladding (e.g. **Morin Perforated Panels**) or polymer laminated fabrics (e.g. **Trespa Meteon**) [Schindler 2008]. Obviously, depends on the material used, different colour effects are observed. For example **Rockpanels Chameleon[36]** brings an extraordinary and surprising perception to the building. Its

[30] http://www.shutterblinds.com/green.html
[31] http://www.archdaily.com/?p=539032
[32] The Carlsberg logo was designed in 1904 by Thorvald Bindesbøll. The colour is green Pantone 349 [http://hansstol.totaldesign.nl/en/carlsberg.html].
[33] http://www.carlsbergindia.com/experience/breweries/Pages/default.aspx
[34] http://www.archdaily.com/?p=387261
[35] According to M. Sturgeon, Director of the NCS Colour Centre, Le Corbusier was inspired by this BP greenery in the colour choice for Villa Savoye (Poissy-sur-Siene, France 1930). The lower level of the mostly white villa is painted green to allude to the perception of a floating volume and blend it with the surroundings [http://www.ncscolour.co.uk/pdf_downloads/Le_corbusier_colours.pdf]
[36] http://www.rockpanel.co.uk/products/rockpanel+chameleon

unique crystal layer which, depending on the angle from which it's viewed and the effect of light, appears to dramatically change colour, as in Landeskindergarten Hollabrunn by Maurer & Partner ZT GmbH (Austria)[37].

But in the architectural history especially one green material - **patinated copper** - plays distinctive role. Due to the natural oxidation process, copper's most recognizable trait is its colour change from a bright orange through iridescent brown finally to a greenish verdigris. Depending on the atmospheric conditions, this patination process can take 5 years in a severe marine environment to 50 years in a dry country location[38]. This metal's distinctive green patina has been applied by architects and designers for thousands of years. Initially, copper was reserved mainly for public institutions, such as churches, universities and government buildings. Even today, copper roofs are one of the most architecturally distinguishable features of these structures. Probably the most recognizable structure covered by copper plates is The Statue of Liberty - a colossal neoclassical sculpture located on Liberty Island in New York City (United States). The statue, designed by Frédéric Auguste Bartholdi in 1886, was a gift to the United States from the people of France. This monumental sculpture - both an icon of freedom and a symbol of United States - originally brown, over the 30 years slowly turned to the present green colour. Contemporary architects sometimes request a particular patina colour at installation. Factory-applied chemically induced pre-patination systems can produce a wide range of coloured finishes similar to natural patination, such as Zahner's Star Blue™ Copper[39]. This patina has only been used on a select few projects e.g. in University of Toronto Instructional Building (or IB Building) by Shore Tilbe Perkins+Will, Mississauga (Canada 2011). Pre-oxidized copper-clad facade distinguishes also famous Renzo Piano's NEMO (National Center for Science and Technology) in Amsterdam (The Netherlands 1997)[40]. The tall exterior walls of the Church in Laajasalo (Helsinki, Finland 2003) by architects Kari Jarvinen and Merja Nieminen are protected by green patinated, board-wide strips of copper, as well[41].

7. Green as a symbol / idea

Last, but not least category touches the more symbolical aspects of green colour in architecture, which goes beyond the simply aesthetic or functional issues.

7.1. Green is not "green"

Since the environmental justice movement's of the 1970s, **green has become a symbol of ecological purity, environmental consciousness and the ecopolitics**. In popular terms, *greening* is used as a metaphor for the practices towards sustainability, minimizing environmental impacts and energy consumption. John Charles Ryan [2012] proposed for this tendency term "green tropism", which he defines as *"a cultural leaning toward greenness"* Over the years *"the green proves to work as the quickest and easiest representation of sustainability"* [Jarz 2011].

37 http://www.heinze.de/architekturobjekt/landeskindergarten-hollabrunn/11494682
38 http://www.artiroof.co.uk/copper.html
39 http://www.azahner.com/surfaces_star.cfm
40 http://www.rpbw.com/project/39/nemo-national-center-for-science-and-technology/
41 http://www.copper.org/applications/architecture/arch_dhb/additional/finishes/

But, contemporary slogan proclaims that *"green is not a colour - it is the state of mind"*. Nowadays "green architecture" doesn't usually mean "green coloured architecture", but is understood as environmentally friendly and energy-efficient, designed in accordance with the principles of sustainable development. Similarly, "green building" is defined as designed to reduce or eliminate the negative impact of buildings on the environment and its users. Thus, **green is very often not "green".**

7.2. Green as a symbol of cleanliness and healthy environment

According to Verena M. Schindler [2008], today **green often represents cleanliness,** as a metonymy for clean technologies such as zero greenhouse gas emissions. Similarly, in the aim to satisfy the desire to live in a 'green' and 'healthy' environment green usually stands for health. Through the growing ecological consciousness green become an "emblematic" colour of building's sustainability for "*'green' buildings simply need to be green"* [Jarz 2011]. This is visible in e.g. **municipal waste incineration plants,** which exterior **green colour serves as a visual representation of the ecological solutions and technologies used inside.** Numerous waste thermal treatment plants were designed in last few years with the elements of green colour, such as polish: ZTPO in Cracow designed by PROCHEM S.A./ POSCO Engineering & Construction (2013) or Municipal Waste Incineration Plant for Metropolitan Area of Bydgoszcz-Toruń by Astaldi SpA and Termomeccanica Ecologia S.C. (2013). The same colour philosophy is found in the Urban Solid Waste Collection Central by Vaillo + Irigaray in Huarte (Spain 2009). The façade is made of recycled aluminum sheets, that have been painted a poppy lime green[42]. An interesting reference to the cleanliness is observed in Public Toilets, designed by Gramazio & Kohler in the city park of Uster (Switzerland 2011), which has a complex facade of 295 folded aluminum strips in the slightly different green colour shades[43]. As green colour evokes particular **associations with vegetation, fertility and growth** [Ryan 2012] it is not surprising, that it is often use as a dominate colour in **food factories**, especially those which carry on organic and ecological production. Such green colour use is found e.g. in Rizzi Group - Selimex Office Building by Werner Tscholl, located in Latsch (Italy)[44] as well as in organic food plant Tony's Farm by Playze in Shanghai (China 2012)[45]. Herzog & de Meuron designed few green coloured buildings for Ricola Ltd. - one of the most modern and innovative manufacturers of herb drops in the world, as Ricola-Europe SA, Production and Storage Building in Mulhouse-Brunstatt (France 1993)[46] and Headquarters Ricola, Marketing Building in Laufen (Switzerland 1999)[47].

7.3. Green as a symbol of youth and educational growth

Symbolical connotations between green colour and growth – understood in terms of the culture and education, as well as youth, are oftentimes reflected in kindergardens, schools and university buildings. In the Kindergarten Sighartstein by

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[42] http://www.archdaily.com/?p=73723
[43] http://www.archdaily.com/?p=260491
[44] www.werner-tscholl.com
[45] http://www.archdaily.com/?p=311024
[46] https://www.herzogdemeuron.com/index/projects/complete-works/076-100/094-ricola-europe-production-and-storage-building.html
[47] https://www.herzogdemeuron.com/index/projects/complete-works/151-175/154-ricola-marketing-building.html

Kadawittfeldarchitektur (Austria 2009) architects consciously reduced the colour scheme to the single tone variation of “green grass”. As the kindergarten is the first station of education, they have chosen green as the *“colour of life, youth, and spring”* [48]. Similarly, in Sant Pere Pescador Kindergarden by Abar + Ovidi Alum (Girona, Spain), green conveys here the notion of freshness and youth, but also immaturity[49]. Also, the Freiherr vom Stein School by Kresing Architekten in Münster (Germany 2006) is consequently green. *“A new understanding of the school emerges – it is not about education in a limited domain, but rather about fundamental cultural growth”* [Linz 2009 p.148-153]. In China, colour *qīng* in Wu Xing (Five Elements) tradition is associated with the element of Wood, the eastern direction and spring season, thus represents nature, vitality and health. As a sign of youth and spring rebirth, roof of the palace of the princes - successors to the throne, located in the eastern part of Beijing's Forbidden City is covered with green glazed tile [Lee 2012]. The same symbolic is visible in the Youth Center of Qingpu by Atelier Deshaus in Shanghai (China 2012)[50], where green and yellow volumes are additionally covered with “white of innocence”.

Fig. 1. Examples of the green colour application in architecture (collage by author on base of her own photograps)

8. Summary – “Green is the New Black”

Paraphrasing the song of the Kermit the Frog, it is easy being green today: *“When green is all there is to be […] I am green and it'll do fine, it's beautiful and I think it's what I want to be”* [51]. Nowadays, colour green, one of the most powerful symbol of sustainable design [Rawsthorn 2010] seems to be the most dynamic colour in architecture, as well [Schindler 2008]. Presented categories prove, that green is today seen as modern, fashionable architectural colour. Green in simply the New Black.

[48] http://www.archdaily.com/?p=34252
[49] http://www.archdaily.com/?p=216907
[50] http://www.archdaily.com/?p=238004
[51] "Bein' Green" (also known as "Green") is a popular song written by Joe Raposo, originally performed by Jim Henson as Kermit the Frog on Sesame Street and The Muppet Show.

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Perception of Colorscape in Naghsh-e Jahan Square,

(Isfahan, Iran)

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1. Introduction

Color and its infinite variety were used as individual taste in caves' walls, earthenware, handcrafts and clothes [1], which were usually extracted from flowers, plants or metals [2]. Todays, application of colors outspread even in **cityscapes**, which is public and it is produced as a chemical-industrial product. It seems, this modern phenomenon is not integrated and monolithic as old habitats' **colorscape** [3] because of the changing in quiddity of life [4]. Since colors have **psychological** impact [5] then it is necessary to apply proper color pallet in this modern era for public and private places. So, this research is recorded the color vision perception of Naghsh-e Jahan Sq in iran by almost 400 years old as an old urban spaces with traditional city color palate.

2.Colopscape, Color Plan, Color Pallet

2.1.Perception of colorscape

Gifford [6] believes that "*environment perception* is the initial gathering of information. We primarily are visual beings, but environmental perception include the ways and means by which we collect information through all our ***sense***." He believe that "one way to ***understand the people color perception*** is to ask them what they see, smell, touch, taste or hear that is called *Self-Report Method* which include *interview*, *checklist*, *questionnaires* and *free descriptions* and it is important to consider the *Personal, cultural* and *physical influence*". Besides, According to Golkar [7] ***perception of cityscape*** is the first step in interaction between "man" and the "city phenomena", it will be done by the ***eye of the head*** while ***eye of the heart*** could be saved the image of the city and it is measured by men's cognition, so, colorscape is not exceptional either. The chart below shows the regularity of cityscape/image. (See Fig. 1),

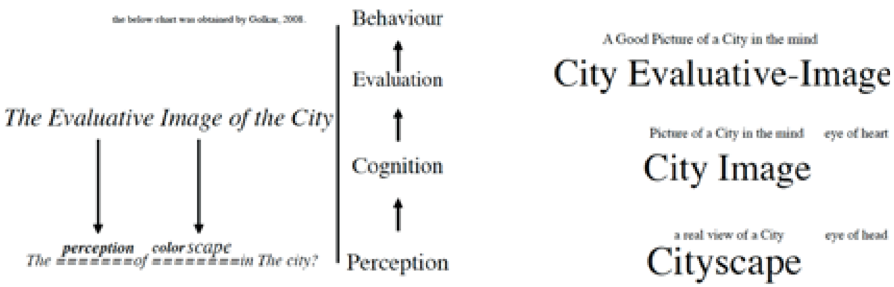

Fig. 1 – The interaction between man and the city phenomena

2.2. Turin 's color plan

Turin (See Fig. 2), in Italy is the city that was planed to have a color plan in 1800s. Brino [8] stated "this color plan originated in the baroque period during the reign of Victor Amadeus II-the king of Sardinia and the founder of the Baroque city in the *second half of the seventeenth century*. But it was never fully implemented due to the intervention of war and pestilence". It was restored in between 1978 and 1983.

Fig. 2 – Turin

2.3. Color palette

In 1960s a French couple, Jean-Philippe Lenclos and Dominique Lenclos, collected the ***chromatic physiognomy*** of plenty of ***popular habitats*** around the world such as Shibam in Yamen, Pueblos blancos in Andalusia Spain, Yazd in Iran (See Fig. 3), South Africa, Karpathos in Greek islands, in a model of palette and pictures.

Fig. 3 – a sample of Yazd Color palette

3. Methodology

In summer 2014, 40 people, tourists and locals, were answered this question: *"What is your perception of colorscape in this square?"*. The interviewees were walking or Sat next to the shops and chambers, which is located in square wall. Others were in the center of the square. They were from different cities of Iran also different countries. Their *personal, cultural* and *physical influence*s were different. Although Gifford believes that for understanding perception one should talk about her/his 5 senses they didn't say exactly about their *hear, smell, touch* and *taste*. At first sight all people explained their vision sense. Checklist, questionnaires and free descriptions were not spotted. Just interview was used in order to find the answer. The color palette of Naghsh-e Jahan Square was not extracted. This field research was started in the afternoon and it takes until the sunset.

4. Case Study: The Naghsh-e Jahan Square

The Naghsh-e Jahan Square was located in Esfahan city, Iran. It is 560 meters long and by 160 meters wide. It is one of UNESCO's World Heritage Sites. It was constructed in the Safavid era between 1598 and 1629 (see Fig. 1). It is usually full of tourists.

1500	2015
	
	

Fig. 4 – The Naghsh-e Jahan Square

	
Tourists from Spain	The shops

Fig. 5 – The Naghsh-e Jahan Square Wall

4.1. Result

All the interviews were written in below table (see tab.1). Nationality, age and major of interviewers also mentioned.

No	From	Major	Age	Colorscape	Perception
	Isfahan	Mathematics	26	Blue	Faith
2	Isfahan	Housewife	-	Blue	Happiness
3	Isfahan	Literature	33	Green	Happiness Vitality
4	Mashhad	Psychology	46	Blue	Pacification-Spirituality
5	Tehran	Civ. Eng.	31	Green	
6	France	Environment. Eng.	30	Blue	
7	Slovenia	Teacher	52	Green	Peace-life
8	Slovenia	Teacher	51	Blue	
9	Shiraz	Student	16	Green	Soothing
10	Isfahan	Chemistry	24	Turquoise blue	Pacification
11	Spain	Teacher	44	Turquois	Sky
12	Spain	Teacher	48	Blue	Hope
13	Spain	Teacher	64		Sea
14	France	Urban .Des	37	Blue	Sky-Persia
15	Isfahan	Architecture	22	Khaki	Warm-Intimacy
16	France	Mathematics	41	Blue	Life
17	Switzerland	Medical Stu.	22	Gray	Connection between Sky-Earth
18	Switzerland	Optometrist	33	Blue	Hope
19	Isfahan	Law	20	Khaki	History
20	Isfahan	Worker	60	Khaki	Pacification
21	Isfahan	Housewife	53	Turquoise blue	Pacification
22	Isfahan	Translator	20	Khaki	Pacification
23	Isfahan	Business	19		Pacification
24	Tehran	Law	26	Indigo blue	Pacification
25	Isfahan	Electronic	30	Turquoise	Mystical
26	Germany	Political Science St	22	Blue	Joy
27	Poland	Journalist	26	Green	Relaxing
28	Shiraz	Student	14	Turquoise	Power
29	Shiraz	Industry	31	Turquoise	Nature
30	Isfahan	Housewife	50	Green	Interesting
31	Belgium	Business	61	Blue-Ocher	
32	Isfahan	Arch St	22	Khaki	
33	Isfahan			Turquoise	
34	France		30	Khaki	
35	France		30	Khaki	
36	USA	Housewife	60	Blue	Peace
37	Tehran			Blue	Life
38	Isfahan	Arch St	27	Blue	Happiness
39	Isfahan	Arch St	20	Blue	Happiness
40	Tehran	Arch St	37	Blue	Status

Tab 1 – interviews' result

Almost 40 people were asked about their perception of colorscape in Naghsh-e Jahan Square. 24 people are from Iran, and the rest are foreigners.

Number	11	3	3	1
Iran	Isfahan	Tehran	Shiraz	Mashhad
Which part of Iran	Center	North	Sought	East

Tab 2 – number of Iranian who answered the research question

5	1	2	3	2	1	1	1
France	Belgium	Slovenia	Spain	Switzerland	German	Poland	U.S.A

Tab 3 – number of foreigners who answered the research question

5. Conclusion

The answer shows that the blue is a dominant color of this square with the senses like pacification, joy, hope, life, nature, sky, mystic and happiness. There was not any explanation about type of this color blue.

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Chromatic environmental integration of architectural surfaces: technologies and case studies

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1. Introduction

The introduction and application of new products in the building market, joined to the continuous elaboration and re-proposition of already known materials, in particular of those dedicated to the facades, produces new effects in the perception of the chromatic truth of the places where these are employed. Among these products and materials there are someone, employed in multiple shapes, finishes and textures, those use has been consolidated in the realization of architectural facades. Their presence in the context in which they insist produces particular chromatic effects, different from those of the tradition or similar to it.
In this "crisis of superabundance" we have the efforts of many researchers of architecture, in transferring the teaching skills acquired through years of research in the color design of buildings. The teaching of color in architecture, despite the fundamental experiences of the past, such as those of the schools of applied arts (Vchutemas, Bauhaus, the school of Ulm etc.) and the international great interest in various scientific fields that we know today (AIC), is still too limited. Indeed, some Italian academy continues to put aside these issues, teaching architectural design in black and white. In some cases some want to even deny the interdisciplinary nature of the topic, arguing that building technology should not deal with color design as if the materials and technologies were not equipped with color.
The sensible world is undeniably colored. Contemporary architects make extensive use of materials and technologies where color plays a central role. It is therefore difficult to deny that the color has a strategic importance in the definition of the environment, in its perception and therefore in its quality that is (with no doubt) reflected in the behavior of the individuals in our contemporary society.
Because of these considerations and the state of things, the interrelationship between forms, surfaces and colors of architectural envelopes that today designers can create, seems to be able to determine a range of solutions that are difficult to control by those who do not possess the tools of the more established worldwide architectural firms. It may happen that, provided with cultural reference models taken out of their context, a less educated designer is brought to rely imitation of what has most influenced him, leaving to his personal taste the construction of color relationship of his work. Thus, it would seem necessary to explore these issues, considering new expressive potential offered by contemporary materials, because also of the growing use of these in the realization of the facades: the most visible part of the buildings.
The purpose of this work, already complex given the amount of information to be checked, it may look in vain if the research field is too broad. We will limit ourselves therefore to treat only those materials and the technologies for the realization of static claddings (no media façade, dynamic façade or smart technologies). Then, dealing with architectural skins where there are no electronic devices to control the color, the color variations of the surface should be totally

related to the physical characteristics of the material and its relationships with the surrounding environment. The amount of variables involved could still afford to think in terms of classification of color agreements and color contrasts, trying, at least for the moment, to abstract our thoughts from the fact that "the world of each of us has been invaded by a lot of signals to which we have tried to respond through an uncritical permeability, trying to preserve at least our biological abilities of survival, according to bio-economy. To feel immersed in an undefined and indefinable confused state dotted with some flash of clarity is the consequence of the bombardment of information of everyday life" [1].

2. Chromatic analysis

This research, which began in 2003/04 with a master degree thesis [2], continued with a PhD thesis (2007/09) [3] and with the research entitled "Sustainable innovation for architecture: materials, technologies and products" (2013/14) [4], conducted first among the “Color and Light” Research Unit at Iuav University of Venice and then among Eterotopie Research Centre has operated as a first approach a screening of the production of materials and building components. The materials we considered are: plaster, wood, ceramics, concrete, metals, glass, plastics, textiles, composites. This operation took place on two main areas of the research: the market of manufacturers (books, websites, catalogs, conferences, fairs and direct contacts with them) and the production of architecture from the late eighties to the present day (books, magazines, visiting places), giving more prominence to works created after year 2000. Once we have gathered as much information on each product and each case study of realized buildings, we proceeded with cataloging them. For each material were identified: basic materials, changes in color, type of surface finish, application examples in architecture. To complete the cataloging we have chosen to prepare a simple graphic scheme that uses a chromatic detection principle already used by researchers in the Department of Technologies for the Built Environment of the School of Architecture (based in Pescara) of University "G. D'Annunzio "of Chieti-Pescara. “We proceeded with the detection of the main colors to consider, obtaining the initial data from the photographic images and from the analysis performed on sight. [...] Using processing software and photo editing and instrumental colorimetry, from the images of the landscape were extrapolated color patches on which further research” [5]. In photo editing software the pixel filter allows, blurring the initial image, to detect the dominant tone of framework in analysis (we always try to frame the building with a good portion of around). The result can be approximated to one, two, three or four main colors that could constitute colors agreements or color contrasts obtainable from Itten classical theory of colors.
In computer graphics pixels are point elements that make up the digital representation of a raster image, for example on a display device or in the memory of a computer. Each pixel has only one color. The pixel filter approximates pixels with colors related to each other in a single color, simplifying the image which is reduced to a few colors overall, blurring itself. The percentage of approximation of colors can be adjusted from time to time, especially in cases where the building façade has projecting or recessed colored elements.

The color of the same building, depending on the material that is used (eg metal) can be perceived differently in relation to the external environmental conditions (changes in color of the sky and natural light, fog or snow, etc.). In some cases it was possible to obtain images of the building in different environmental conditions and to operate analysis on them. For reasons of space in this paper there cannot be an exhaustive treatment of the subject.
The working method is deliberately simplified with the goal of identifying the basic colors of the skin of the building so as to analyze them, for example, according to the color theories of Itten. "The chromatic fact is the pigment, i.e. the coloring material that can be determined and analyzed from a physico-chemical point of view, which assumes its content and meaning through human perception through the retina and the brain. The eye and the mind can achieve an exact perception only for comparison or contrast. [...] The color evaluation, in contrast to the physico-chemical fact of color, constitutes the psycho-physical fact of color that I define the chromatic effect. Physical reality and color effects are identified only in harmonic chords. In all other cases, the reality of the color is changed simultaneously, producing a new, different effect" [6].
In addition to the issues related to the change in the size of the visual field, we have taken note of the limits imposed by the studies that have made an important contribution on the three-dimensional use of the material "color" (to be precise, we believe that even color is a material of construction). "Even photography is the two-dimensional representation - that we read as truth - a three-dimensional reality. A higher order cannot be explained by a lower one, therefore it is not possible to realistically represent a work created in three dimensions through the use of two dimensions" [7].
Considering what has emerged from the work of cataloging we proceeded to a classification of the color agreements and contrasts detected in the case history (buildings).
This phase of the work, in addition to providing an overview of the color characteristics of some of the contemporary materials, could lead to more in-depth considerations about their use in the skin of the buildings and above all it could allows us to identify which of these best fit in some contexts and which you can use if you want to achieve certain effects.

Later then we proceeded to a classification of the color effects obtained with certain materials and finishes:

- Merger with natural elements of the environment (ground, sky, vegetation).
- Dematerialization of the building (gray, mirrored surfaces).
- Contrast of primary colors (red-blue). For example, between the building and the sky.
- Contrast of complementary colors (i.e. red Vs green). For example, between the building and vegetation.
- Combinations of colors only in the facade (multicolored facades).
- Highlighting specific architectural elements (projecting parts, backward elements, etc.).

- Contrast of light and dark to highlight some shapes.
- Color totally divorced from the context: to create a "stranger".

Please note that the pixel filter method is not effective in all cases. For example when the building façade is composed of projecting elements it looks easier to perform the analysis on non pixelated images. The same thing can be said for what concerns the architectural skins that feature many different colors, such as the buildings of Sauerbruch & Hutton architects. In this case the pixel filter produces a background noise, mixing all the colors to gray or brown.

"If in the field of materials we assumes, for example, a base material subjected to a process of transformation, we get something that is different from the material we used and which is the product. Similarly, when you design, you introduce into the design process (similar to a machine) the basic materials, consisting of all the information needed to design [...] and you transform them into the particular product represented by all the documents of the design" [8]. The process that runs in the color composition looks very similar. Color theory and contemporary research seem to demonstrate that the combination of the materials in the skin of the building and the relationships that the skin establishes with what is around us belong to the same logic of the project.

3. Examples of case studies and their classification

Now follows a selection of the case studies we have analyzed, classified according to the color effects obtained with certain materials and finishes.

3.1. Merger with natural elements of the environment

An example of this color effect could be the New Metropolis Museum in Amsterdam by Renzo Piano (1997). The building is located in the harbor of the Dutch city, beneath it lies a body of water, above it a clear sky from deep blue color that is reflected on the water. Viewed through the pixel filter, when the body of water and the sky expand into a panoramic vision, the building tends to disappear in the context. We can appreciate a similar effect by night (Fig. 1). The texture formed by vertical rectangular elements disappears, the green color of the copper is partially absorbed in the blue water and partially in the blue sky.

Fig. 1 - New Metropolis Museum (NEMO), Amsterdam (1997) by Renzo Piano. Photo of the building in its context treated with pixel filter (2 different environmental conditions). Photo editing © Alessandro Premier

3.2. Dematerialization of the building envelope

Another case study for ceramic materials is the Music Hall and House in Alguena, Spain, 2011, by COR Asociados. The cladding of the music hall is completely covered with pearlescent ceramic with a mirror finish. This finish reflects the colors that surround the building blending with the environment (Fig. 2). In fact, with the pixel filter the building seems to disappear, leaving only the colors of the blue sky and of the earth.

Fig. 2 - Music Hall and House in Alguena, Spain (2011) by COR Asociados. Façade reflecting the colors of the environment. Photo © David Frutos.

3.3. Contrast of primary colors

Among GRC (Glass Fiber Reinforced Concrete) claddings there is Soccer City Stadium in Soweto in South Africa, by Boogertman + Partners and Populous. The large envelope is clad in panels of GRC colored by earthy colors. The shape looks like a traditional African pot: the Calabash. The pixel filter shows that the building merges with the color of the earth in contrast with the blue sky in a game of primary colors contrast (red and blue), according to Itten color theory (Fig. 3).

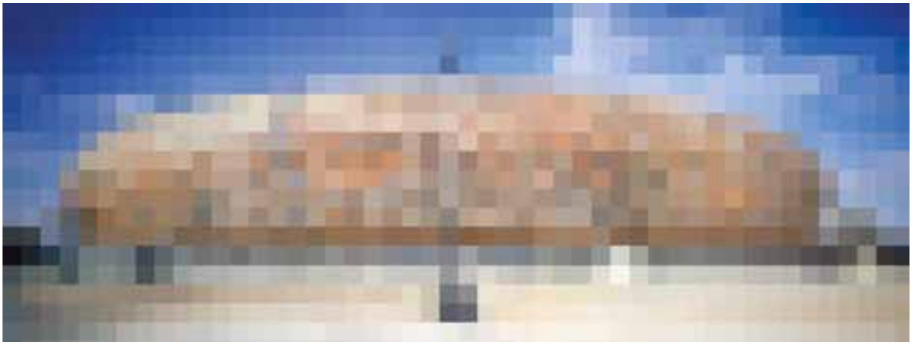

Fig. 3 – Soccer City Stadium, Soweto, South Africa (2010) by Boogertman + Partners and Populous. Photo of the main façade treated with pixel filter. Photo editing © Alessandro Premier

3.4. Contrast of complementary colors

Among the metal claddings we analyzed the Parking Structure Art Façade in Indianapolis (USA), 2014, by Urbana. The large flat facade of the parking is characterized by metal strips colored in blue and yellow (Fig. 4). The strips, similar to many post-it, are bent and positioned so that the building, from one side, appears completely blue and from the other side completely yellow. The building was designed to be seen in motion so that the façade, while being static, seems dynamic, due to a change in color between yellow and blue. "A field of 7,000 angled metal panels in conjunction with an articulated east/west color strategy creates a dynamic façade system that offers observers a unique visual experience depending on their vantage point and the pace at which they are moving through the site. In this way, pedestrians and slow moving vehicles within close proximity to the hospital will experience a noticeable, dappled shift in color and transparency as they move across the hospital grounds, while motorists driving along W. Michigan Street will experience a faster, gradient color shift which changes depending on their direction of travel" [9]. In this case the pixel filter is not effective, while the direct reading of the images allows the immediate understanding of the effect obtained.

Fig. 4 - Parking Structure Art Façade, Indianapolis, IN, USA (2014) by Urbana Studio (Rob Ley). Photo © Serge Hoeltschi.

3.5. Combinations of colors only in the facade

A similar game was played by Architecture Studio in the glass envelope of Advancia School of Business, in Paris, 2010. The facades are characterized by blades of frosted glass in red and yellow color. In some places the alternation of the two colors produces an effect of interpenetration. According to Itten color theory this is a contrast of pure colors (Fig. 5). The color contrast is only in the façades of the building.

Fig. 5 – Advancia School of Business, Paris (2010) by Architecture Studio. Photo editing © Alessandro Premier

3.6. Highlighting specific architectural elements

Among concrete envelopes we analyzed the Asylum Les Cabanyes in Barcelona, 2008-2010, by Arqtel architecture. The building is entirely made in grey concrete, while the parts set back from the front edge are brightly colored. Window holes and lodges have surfaces colored in red, orange, yellow and green (Fig. 6). With the pixel filter gray surfaces seem to disappear highlighting the blue sky and the colors red and green in the portico. The contrast of complementary colors is just in front of the building highlighting specific architectural elements like windows holes.

Fig. 6 – Asylum Les Cabanyes, Barcelona (2010) by Arqtel. Photo editing © Alessandro Premier

3.7. Contrast of light and dark to highlight some shapes

Among the buildings with textile surfaces there is the Basketball Arena in London, 2012, by Wilkinson Eyre Architects. The envelope is made with a membrane made of polyester fiber coated with PVC. The membrane is stretched over a curved tubular structure in aluminum so as to assume a wavy and jagged shape. On the completely white facades there is a contrast of light and dark color (according to Itten) made by shadows that highlights the shapes drawn by the designers (Fig. 7).

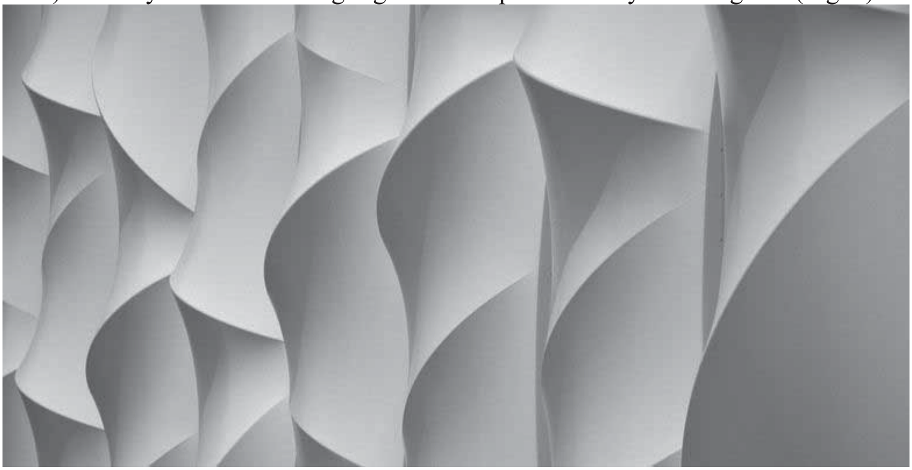

Fig. 7 – Basketball Arena, London (2012) by Wilkinson Eire Architects. Photo editing © Alessandro Premier

3.8. Color totally divorced from the context

Among claddings made with composite materials there is the Seeko'o Hotel in Bordeaux, 2007, by Atelier King Kong. The building envelope, made of Corian©, is completely white. The building is so completely divorced from the context: almost an alien in shape and color (Fig. 8).

Fig. 7 – Seeko'o Hotel, Bordeaux (2007) by Atelier King Kong. Photo editing © Alessandro Premier

4. Conclusions

As may be inferred from these brief remarks, it seems possible to trace in numerous architectural compositions, the will of designers to try chromatic harmonies and discords through the tools provided, for example, by the old theory of colors from Itten. It is well documented in articles and monographs as contemporary architects do preliminary studies on color during the design process of building facades. The research of Sauerbruch & Hutton architects is well known, but also those of Herzog & de Meuron. Even less celebrated architects and artists, such as Rob Ley of Urbana Studio (designer of the case study Parking Structure Art Facade), perform a very complex work in this direction with the goal of making the building more human through a visual relationship with people who live in the city or in the district. The color becomes an essential element of the design because it cannot be divorced from the shape of the individual elements that make up the facade cladding and it is strategic because without it you cannot achieve the final goal of the project.
During the research we also found that, with a great probability, the surface processing of materials interferes on the color of the claddings, introducing shadows, chiaroscuro effects, breaking reflected figures. The contemporary colors are closely related to the materials and technologies that produce them and they cannot be used without a proper knowledge of these technologies. Despite the desire of some academy to keep in the corner these studies, now it seems increasingly essential to place them in evidence and to intensify the research efforts in this direction.

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La recherche de l'espace, de la lumière, de la joie, de la sérénité, nous invite à faire appel à la couleur fille de la lumière[i]
Le Corbusier [1]

1. Introduction

This paper aims to reveal the importance that the study of light and colour should take in the decisions of the architectural project from its beginning to its implementation on the working site.
The colour among architects is often thought as something that is added at the end of the architectural process, often already at the working site, and when in doubt always using white. According to this idea, Werner Spillmann observed that colour decisions usually came when everything is already determined; that is, most often colour was considered in the very last moment within an extremely short time period without any consideration of the building structure, function and surroundings [2].
On the other hand, light is considered a mysterious and elusive entity, something that many architects talk about, but only few can really master. And if we consider artificial lighting, most of them rely on electrical engineers to control the space appearance when sunlight is not enough, or at nightime.
At a time where it is increasingly impossible to control all the aspects of expertise, specific legislation and areas of knowledge that contribute to the development of an architectural project it is natural that the architect look for experts to help him in these various areas. But he should not give up on controling fields that intrinsically belong to architecture and its presentation (meaning communication). And colour and light are certainly among the most important ones for this goal.
For this reason *Light and Colour* should be considered a specific branch of specialisation that could help architects to convey their objectives concerning aesthetical, functional, ergonomic and comfort issues. Colour consultants should work together with light designers to promote the knowledge that architects need to communicate the complex and transdisciplinary objectives of architecture.
To illustrate these premises we present some results of our practice both as Colour Consultant and as Light and Colour teacher at the Faculty of Architecture, University of Lisbon.

2. There is no space perception without light

Fig.1: The interplay between light and matter. Convent of Christ, Tomar, Portugal.

Light is the genesis of visual perception and sight is the main resource for our communication with the space that surrounds us. Therefore, in this two-way process, space communicates with us primarily the way they reflect the light [3]. In fig.1 we can see the importance of the interplay between colour, light and matter: light, coming from the window at the end of the corridor, reveals the quality of the space through the properties of the surfaces like the polished stone and matte ceramic tiles on the floor, glazed tiles (azulejos) and matte lime mortar on the walls and the rythm of the coffered wooden ceiling. Light is a key theme in architecture, not the light in an abstract way, but the relationship between light and matter.

3. Whenever there is light there is colour

As long as we have light in our perceptual field we get surface and volume (and therefore space) information through our eyes from different electromagnetic spectra wavelengths, that is, different colours.

So we can say that it is through the interpretation of the perceived colours that we can sense the space. Colour is the form of space. And that's why it is so important: if colour gives us the perception of a space, we can use it to enhance or to change its perception.

Patrick Heron, a painter cited by Michael Lancaster [4], said:

... for the human eye there is no space without its colour; and no colour that does not create its own space. When you open your eyes the texture of the entire visual field consists of one thing: and that is colour...

Le Corbusier [5] again reveals this intertwined relation between the quality of light and colour perception:

Pour exister véritablement, des tons réclament la pleine lumière (le rouge); la pénombre les tue. D'autres supportent le clair-obscur, mieux que cela; ils y vibrent intensément (certains bleus)[ii].

The perception of a space is derived from the relation between observer, surface and light. Our movement through the space alters the colour perception of the surfaces because this three-way relationship is changed. If the light changes, the colours of the surfaces will change, and our perception of that space will be different. Colours are not immutable properties of the objects, they only exist ephemerally while the light and the observing conditions don't change.

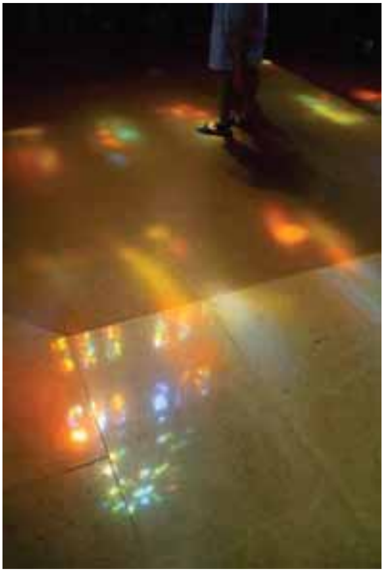

Fig.2: Ephemeral colours. Church of the Holy Family, Barcelona.

The material but also the intangible properties of architecture are revealed to us by colour, and it is through colour, as it is recorded in our memory, that we, architects, think and create new spaces.

It is not understandable the lack of knowledge and the gap between the architects and this inevitable property of architectural image, both in their professional practice, and in architectural education.

baroque and neoclassical palaces. From the "true" colours of the materials to the faked colours of their imitation, from the painted surfaces to the paintings over the surfaces, colour has always been an unavoidable and efficient media used by architects and by architecture to communicate its goals (fig.3).

Fig.3: Colour as communication. XVI century chapel, Moncorvo, Portugal and Max-Joseph-Platz, Munich. Germany

The Modernist Movement react to an over-decoration and to the complexity of this past as well as attempting to make new synthesis out of new concepts, new materials, and abstract aesthetics praising the materials in its own "truth".

However it's not true that Modernist architects don't use or think about colour. Beyond the well-known preconception of the new white architecture conveyed by the black-and-white magazines of the time, they used a lot of colour in painted surfaces and also through the use of coloured materials. Just think of Mies van der Rohe colourful stone plates used in vertical surfaces in Barcelona Pavilion (Fig.4) or the wooden panels in Farnsworth House. In fact every material has its own colour or colours, constituting an important part of the architecture's colour palette. What normally distinguishes the presence of natural materials, like stone or wood, from painted surfaces, is the richness of their visual texture. And remember that this texture is noted by visual perception through colour separation. Materials have always been used for their rich and ornamental colour/texture/surface characteristics, and even Adolf Loos, the herald of Ornament and Crime, used stone and wood panels in this way both in Villa Muller and in the American Bar in Vienna (Fig.4).

Fig.4: Barcelona Pavilion, Mies van der Rohe and Muller House, Adolf Loos

moments of complicity between architects and painters [6]. The Russian avant-garde architects, educated also in the field of painting, used a revolutionary aesthetic, a scenic statement for their aesthetic objectives where the graphic language mingled with the three-dimensional achievements, assuming the red as a symbol of post-revolutionary dynamics designed for a new and more fair world.
The unity of the artwork, combining painting, architecture and all the applied arts, was one of the main points of Weimar's *Staatliche Bauhaus* manifesto published by Walter Gropius in April 1919, whose ultimate goal was the abolition of borders between *Monumental* and *Decorative* arts.
Following these ideas, during the 60´s and 70´s painters and sculptors were invited to conceive and place their work in architectural spaces, but always considering architecture as one thing and the other arts as something else.
We don't want here to discuss colour as an aesthetic feature that could be applied to architecture. We want to state that colour is part of the architecture, and, in that way, it embodies its own premises.
Nowadays we often see architects applying a white paint that was not possible before, based on Titanium dioxide, causing a light reflection that, in most cases, is not advisable for human comfort. When Le Corbusier talked about white referring to it as a *pot de crème* colour (for Maison LaRoche, for instance) he was not referring to Titanium White of course! This misunderstanding about the use of the colour white finds its contrast in some architects' opposite approach, using colour just to follow some painting and sculpture contemporary trends, without centring its use in the realm of the architecture discipline.
Although architecture find its richness in the plurality of its various expressions, I believe that colour should find its place in the communication of architecture in a natural way, supporting and informing the entire creative process, taking a stronger voice when its justified, and remaining almost silent when necessary.

5. Light, colour and education

The lack of a curricular unit in the subject of colour in most architecture schools, where students could receive information and apply it into architecture design laboratory, is obviously a fault. And if we also consider the subject of light integrated in architecture project, the absence is even worse.
Ludovico Quaroni [7] in 1977 stated that:
Ma c'è sempre una notevole ignoranza sul modo di scegliere e comporre i colori, ignoranza che è particolarmente grave per chi, come un architetto, deve per forza di mestiere avere a che fare con essi. I progetti cha escono dalle facoltà di architettura hanno forma, ma non colore, così spesso non sono chiariti nei materiali componenti e cioè nella loro realtà anche tecnologica: si tratta spesso di astrazione più o meno gradevoli, o di pure esercitazione grafiche. [iii]
This general lack of knowledge concerning colour, comes from the architect's education and still remains today.
In response to this gap, the work of Werner Spillmann comes with special relevance, both in his role as a Colour Consultant linked to architecture (his work with Rob Krier for instance), in which advocates the integration of Colour Study in Architectural Project from its early stages, as well as his action as a teacher, considering colour as a primary component in the education of Architects.

6. Light and colour in the design process

From our experience as a Colour Consultant we have developed three main concerns about light and colour study:
a) Follow Architectural Project goals.
It is fundamental to understand and reinforce the identity of the project at all scales and help to communicate the aesthetical approach of the architect(s) as well as to contribute, through light and colour use, to the definition of its relationship with the natural or the built environment, the relationship between exterior and interior, between different spaces and even between different functions in the interior.
b) Fulfil ergonomic goals.

c) Balance Cultural/Psychological/Aesthetical use of colour with space function.
The balanced use of the cultural, psychological and aesthetical aspects of the colour phenomenon in order to meet the needs and functions of the human being, leads to a successful architectural communication, and to an adequate interaction with its users.
It is very important to clearly understand the rationale behind the main architectural ideas from the beginning, in order to reinforce them through the light and colour study.
In order to develop the right colour and light atmospheres for each space, we use Frank Mahnke [8] idea to establish a profile (*Polarity Profile*) that by opposing concepts, allows you to define the characteristics of the environments to be created: calm/dynamic, hot/cold; casual/institutional, etc. This idea helped us to continually question the fundamental reasons for the application of certain colour palette or a certain light solution to each specific space at the design stage.

7. The stages of the Colour Study

a) Survey
Our first contribution for the project is to complement the historic and iconographic information about the site with a colour survey. This survey should always include data from the natural and artificial environment, and the data from the building, if it is a renovation process (fig.5). For heritage sites we should follow a complete and rigorous survey intertwined with restoration processes and qualified technicians and specialists.

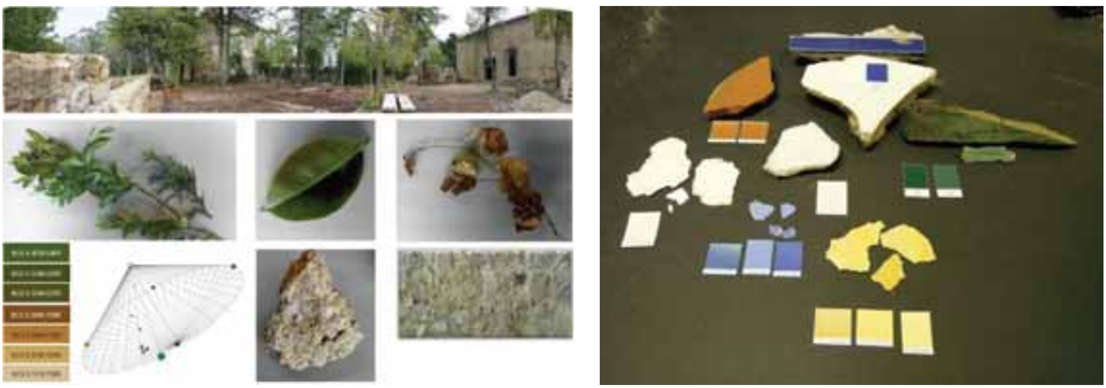

Fig.5: Colour survey examples

b) Conceptual design goals and general approach.
In this stage we discuss the main concepts of the architectural project and how the colour study could help to define them, from the relationship with the environment to the interior design.
c) First ideas.
In this stage we propose colour palettes for the main spaces, discussing materials, textures and finishing. The spaces are divided in classes for their functional characteristics (Fig.6).

Fig.6: Discussion of the first ideas: CVDB and LGLS architecture studios.

Fig.7: Colour, materials and lighting simulation: CVDB and LGLS architecture studios.

e) Written Report and Colour Study

A written report is elaborated supporting the colour study options and a colour palette is presented for each representative space of the project along with the choice of materials. This report and colour study is included in the overall project to be presented to the municipality and/or other institutional services.

f) Communication to the building site

Specific plans and sections of the architectural project with colour representation and notation are developed for a complete understanding of the surfaces to be painted. Written specifications describing the type, characteristics and application procedures of paints and finishes are developed and included in the execution process for the building site (Fig.8).

Fig.8: Final Drawings: CVDB and LGLS architecture studios.

g) Test Stage

From our experience we draw the imperative necessity of testing the light fixtures and the colour palette at the building site, exactly on the places where they will be applied. That’s the place where the final decisions should take place. Light and colour effects are always different from space to space depending on a multitude of factors, and therefore demand a great deal of on-site tests. We have learned that it’s difficult to define “good colours” since a colour that we have used successfully for one space could not be adequate to another, with different geometry, dimension, with other colours nearby, or with different lighting. On this, the teachings of Josef Albers [9] are precious: he stated in his pleasant for the authors) from the use of the spaces after the completion of the project, in order to gain experience and to draw conclusions for further studies.

9. Conclusions

The Light and Colour Study should be understood as a competing skill for the quality of the project, such as Structure, Electrical Installations, Water and Sewage, Heating, Ventilation and Air Conditioning, etc., and should accompany all stages of architectural design, from the first ideas to the building site tests.

The Colour Study should support and enhance the formal and functional options of the Architectural Project, leaning on the choices of materials, coatings, finishes and, together with the light design, on how the spaces are perceived, that is, upon the relationship between matter and light (either natural or artificial).

Light and colour are inseparable elements in space perception, promoting its quality, aesthetic relevance, functionality and human comfort and, consequently, its study should take its place in the architectural design process among the other areas of specialisation.

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Environmental Colour: Green Algae in Responsive Architecture and Design

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1. Introduction

For a number of years now Paris has served as an open-air showcase for novel ways to intensify the relationship between architecture and urban greenery. Especially revolutionary, however, is a new ecological approach based on green algae. The underlying strategies of the investigation of 'green' in architecture range from using plants as the inspiration for form and colour—including as simile and even metaphor fuelling the very design concept—to literally using the living vegetation as a constituting material in architecture. Within the French capital and beyond, this paper considers a few such exemplary projects, especially in relation to green algae. In creating their Docks en Seine—City of Fashion and Design in Paris (2008), Jakob + MacFarlane Architects refer to the green foliage of the trees along the Quai d'Austerlitz. This paper proposes a new interpretation by associating the building with the prehistoric seaweed that once flourished in the tropical sea existing at this exact location some 45 million years ago. A second project discussed in this paper is Toyo Ito's Sendai Mediatheque (2000) in Japan, whereby the notion of an aquarium with its algae, seaweed, and phytoplankton is employed metaphorically. Thirdly, XTU Architects' (Paris) use of green microalgae to create bioreactive façades will be discussed. And, also considered is the work of Pierre Calleja, French biochemist and marine aquaculture specialist (Libourne) who has invented CO2-absorbing, microalgae-powered street lamps.

2. Green Algae in Contemporary Architecture

2.1. Jakob + MacFarlane Architects: Architecture Evoking Pre-Historic Green Algae

Located on the left border of the Seine, the Docks en Seine—City of Fashion and Design (2008) by Paris-based Jakob + MacFarlane Architects extends along the riverfront through a new structure—which the architects call a 'plug-over'—that grips the concrete structure of an existing industrial warehouse of 1907 on the sides and on the top. [6]

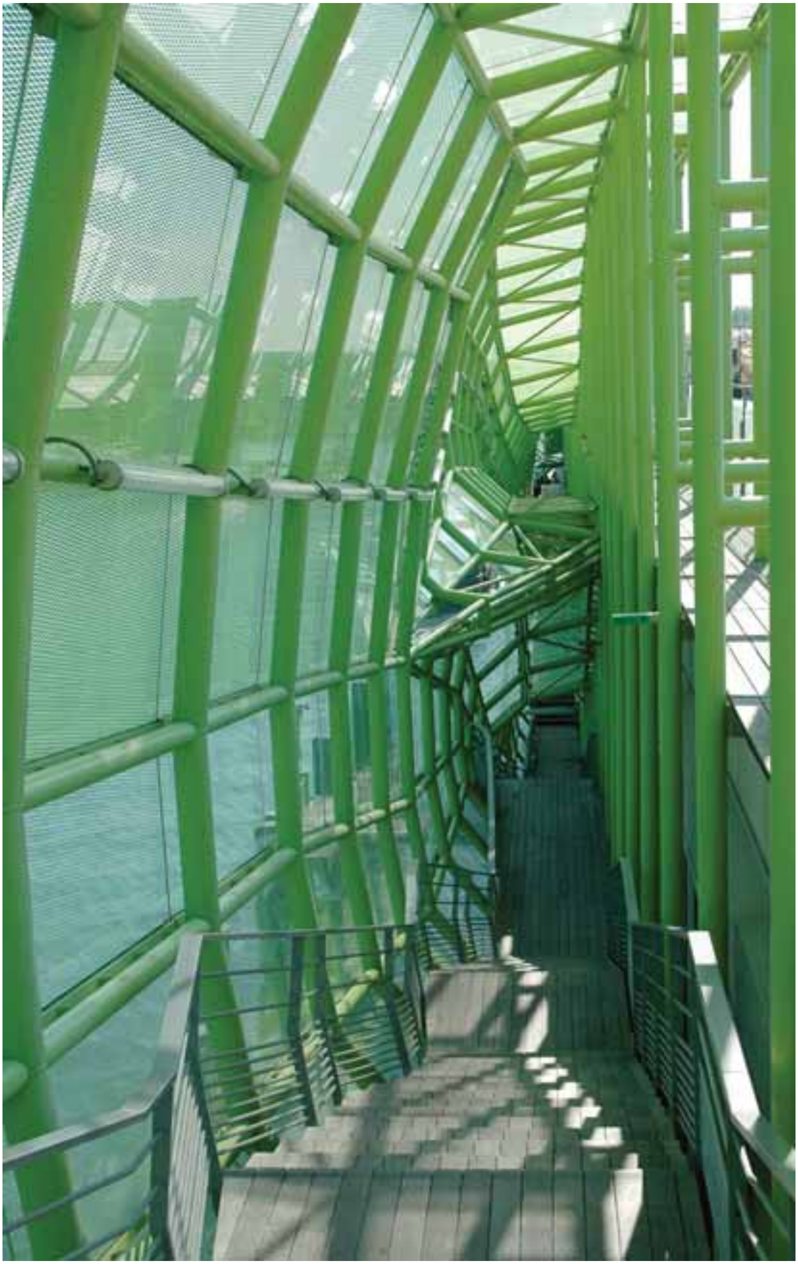

Fig. 1 – Docks en Seine—City of Fashion and Design, conceived by Jakob + MacFarlane, Interior Passage along the Shore of the Seine, Paris, 16 September 2014 © Photo Verena M. Schindler, Zollikon

The intention of the architects was to cover the old building of the Port of Paris with a 'dynamic, active, smart and vegetal skin, which echoes water and nature.' [5] Thereby, an important source of inspiration was the green-coloured, undulating river. The architects also referred to the beautiful green foliage of the trees along the Quai d'Austerlitz, aiming to enhance a continuous green landscape, not only through the colour concept of the building, but also by incorporating a vegetal roof designed by landscape architect Michel Desvignes, which affords superb panoramic views of Paris. [2] No matter what the inspiration or motive, in any case, the green colour of this new architecture contributes to its strangeness. During the day at times it appears to be a kind of olive green, but changes also to a dazzling green.

Beyond the architects' own explanation of the originating design concept, the chromatic aspect of a macrophyte can be associated with the building. [7] Here a new interpretation arises in relating the green to prehistoric seaweed that once might have flourished in the tropical sea existing at this exact location some 45 million years ago. Or, another association of the verdant and fully inflated structures that adhere to the ancient concrete skeleton could be huge vegetal spiders coming from a prehistoric tropical forest.

In the interior they constitute a huge, high, and irregular vault of a simulacrum of greenery embedded in a green-coloured light. (Fig. 1) Needless to say, this mysterious green building provoked a great deal of criticism and had great difficulty in establishing a positive relationship with its neighbours. Even further, Yann Kersalé's lighting design transforms the architecture into a lively spectacle. At night, the 'plug-over' mutates into a mysterious glowing fireworm, flooding the river surface and its movements with luminescent green. At dawn, the effect is fluorescent.

Returning to the association of the macrophyte, the chromatic aspect combined with the dynamic curvature of the new structure calls up the floating vegetal, like a mane of green hair caught in a stream, seaweed gripping the rocks, creating a fresh and moist atmosphere, an ornamentation of the old concrete structure on the shore of the Seine. The French philosopher Gaston Bachelard asks himself whether 'Les herbes retenues par les roseaux ne sont-elles pas déjà la chevelure d'une morte?'[1] He then writes: 'Voilà ce qu'on entend près de la rivière, […], le soupir des plantes molles, la caresse triste et froissée de la verdure'[2] [1]

2.2. Toyo Ito: Architectural Concept Including A Structure Like Algae Dancing in the Water

One of his most distinctive works, Toyo Ito's Sendai Mediatheque (2000) is based—metaphorically—on the concept of an aquarium. Within a glass box, thirteen independent steel-ribbed shafts carry the floor slabs. Like 'algae dancing in the water', these vertical tubular structures serve as light wells with rooftop devices to reflect sunlight down the tubes into the building and also provide vertical connections for cables, wiring, elevators, and stairways.

In 2013, Toyo Ito was awarded the Pritzker Prize 'for his sensitivity to landscape, for infusing his designs with a spiritual dimension, and for the poetics that transcend all his works.' And, in the jury citation it is also said that he 'has drawn on inspiration from the principles of nature, as evidenced by the unity achieved between organic-like structures, surface, and skin.' [8]

3. Microalgae Skin in Responsive Architecture

3.1. Algae-Based Façades for Buildings

If the architecture of the wavy exterior skin of the City of Fashion and Design has been perceived as futuristic, the projects by XTU Architects (in Paris, founded by Anouk Legendre and Nicolas Desmazières) can be considered as ultra-futuristic and utopian. They imagine in the near future that entire floating cities will exist as environmentally friendly, non-polluting, and self-sufficient eco-systems. Anouk Legendre explains that 'green has invaded all our projects.' and that this colour has been 'inspired by the landscape.' [3]
XTU actually proposes a bionic concept—a synthesis of architecture and agriculture—for sustainable cities. Featuring the theme 'Different Ways of Producing and Providing Food,' the architects designed the French pavilion for the 2015 Expo Milano | Feeding the Planet | Energy for Life.

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[1] "The weeds hold back by the reed, aren't they already the hair of a dead?" (Translation by the Author), Gaston Bachelard, L'Eau et les Rêves, p. 102.

[2] "This is what we hear close to the river […] the sigh of soft plants, the sad caress of greenery." (Translation of the Author), Gaston Bachelard, L'Eau et les Rêves, p. 82.

While the underlying strategies of the investigation of ‘green’ in architecture of both Jakob + MacFarlane and Ito use plants as the inspiration for form and colour in fuelling the design concept, the projects by XTU literally use the living microalgae as building material. Niece of agronomists and mother of a biologist, since 2007 Anouk Legendre has conceived of the creation of the photosynthetic biofaçade, a sort of vertical greenhouse where ‘CO2-absorbing planktonic algae are cultivated providing a oleaginous biomass rich in oxygen.’ [4] (Fig. 2)

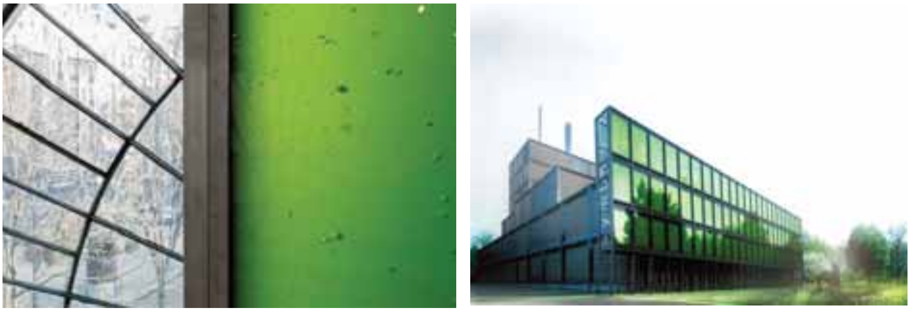

Fig. 2 – Prototype (left) at the exhibition of Pavillon de l’Arsenal in Paris, 2013, © Antoine Espinasseau. SymBio2 (right), biofaçade of a materials recovery facility, 3D rendering, 2011, © XTU Architects

Fig. 3 – Biofaçade (left), detail, photo-bioreactors integrated architecturally and technically in the curtain wall, 2011, © XTU Architects. X Sea Ty Centre (right), concept for a sustainable city, 2009, © XTU Architects, www.x-tu.com

In the intermediate cavity of the glazing units of the photo-bioreactors, there is not only air flowing, but also microalgae. (Fig. 3L) Exposed to light, the double-skin façade serves as a vertical farm of living micro-organisms. They also act as thermal regulators optimizing energy performance in the building. Depending on the time of day, they are more or less opaque according to the density of the biomass, and thus serve as a dynamic solar shading device. In this system the curtain wall forms a symbiotic connection with the building. (Fig. 2R) Collected daily in the late afternoon, the living biomass from algae can then be used for commercial purposes, e.g., by the pharmaceutical, cosmetic and food processing as well as biofuels and bioenergy industries.
The non-polluting city of the future imagined by XTU is composed of two different types of buildings. (Fig. 3R). The first type is built with photosynthetic biofaçades of microalgae, as described above. The second is made of special green concrete upon which CO^2-absorbing vegetation grows. Next to the green river, green forests with palm trees grow on one shore, while on the other sheep graze peacefully on green herbs. Let's imagine such self-sufficient floating cities in the near future!

3.2. Algae-Based Self-Powered Street Lamps

Fig. 4 – Pierre Calleja: CO^2-absorbing and microalgae-powered street lamp. Photo http://www.designboom.com, Photos Courtesy of Fermentalg

French biochemist and marine aquaculture specialist Pierre Calleja, who founded his own firm Fermentalg in 2009, began his research on microalgae some fifteen years ago. Recently he developed a CO^2-absorbing, microalgae-powered lamp that can be used to illuminate outdoor spaces like streets and parks, as well as indoor spaces like offices, shops, and homes. A prototype of the green glowing tube-shaped lamp was tested in Bordeaux, France, in 2012. (Fig. 4)

4. Colour Ranges of Algae

Will green-algae biomimetic architecture be like looking through the glass of a murky aquarium or a submarine? Or, will the city turn into a uniform green-coloured urban space? Colour and visual imaginary plays an important role in ecological discourse. All microalgae projects show an exceptional glowing green colour (Fig. 5, 6), but the reality is different.

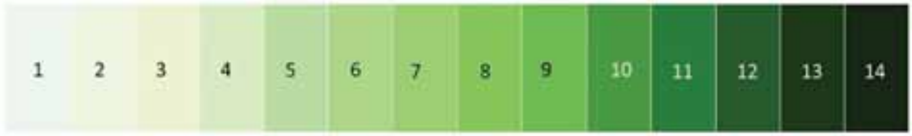

Fig. 5 – Algae colour identification scale, indicating the algae density and ranging from very light shades in transparent container to dark ones with increasing opacity. © 2013 Robert Bair, University of South Florida, https://www.teachengineering.org/view_activity.php?url=collection/usf_/activities/usf_biorecycling/usf_biorecycling_lesson01_activity2.xml

Fig. 6 – Olivier Scheffer, R&D director at XTU in front of an installation of Algobags designed by XTU. © XTU Architects, Paris

The unicellular species of microalgae range in size from a few micrometers to a few hundreds of micrometers. Cultivation conditions such as temperature, illumination, oxygen, and nutrients are important. Vertical growth and a closed-loop system seem to boost the production of live algae.

Olivier Scheffer, R&D Director at XTU Architects, claims that due to the short life cycle of microalgae—from one to three or four days depending on the type—, microalgae change colour from green to bright red. He says that, in effect, all the colours of the rainbow and all qualities from transparent to opacity will be options for biofaçades.

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6. COLOUR AND DESIGN

roduction

market of lipsticks is very rich of different textures. Some are answering for special expectations, in particu ome markets as Asia.

ed, Asian consumers have a good sensory sensibility, and are very efficient in detecting sensory difference arketers requests on new shades that extend the known color environment, compared to the color range at h of the product, some new shades are not OK on a sensory characteristic, noted SC in the following text. e studied lipstick range, the focused SC is a combination of 5 different items : Sliding, Melting, Thicknes sit, Homogeneity and Oily residue.

core formula is the same for whole range. The only varying ingredients are the coloring raw materials and o adjust the texture.

goal of this study are:

to identify which ingredients are more impacting on the texture, and if it exists some formulation solution id sensory differences between shades on this lipstick range

to define precise ranges of values for which the formulas are acceptable, considering the SC. So, it will sible to detect issues, before to make a submission

to explore physical measurements range, and to identify if one ofthem can permit to anticipate sensory issu

terial and methods

rst, we analysed the whole range composition and identified trends for impacting topics on the focused SC. second time, we built a mixture design where enlighted ingredients vary. Each mixture, corresponding to ula, is :

luated by a trained sensory panel

luated by contributors of shade submissions acceptation ; from R&D laboratory, quality control laborat marketing service, through a web-questionnaire

trolled to ensure that samples respect Chanel quality requirements

alyzed by different physical measurement methods, to determine if some of them can help to anticip ry differences.

enerated data were processed by statiscal tools (Principal Composant Anlaysis, Multiple Factoral Analy r regression).

sults

irst step : Identification of statistical correlations between shades composition and obtaining sens acteristic.

nalysed each formula and its OK or KO result on the SC.

method enlighted some ingredients:

Titanium dioxide

Pearls

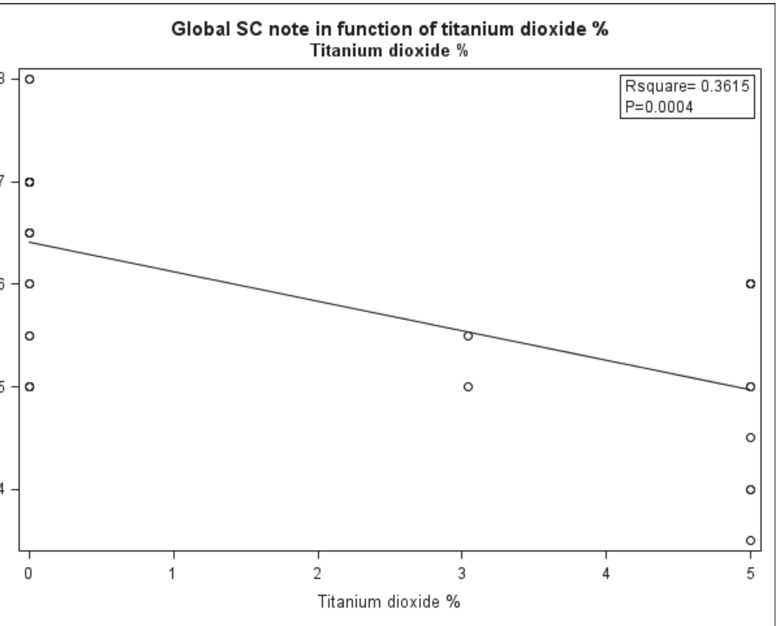
Oil N°1

Oil N°2

D&C Red 30 lake

Colorless base

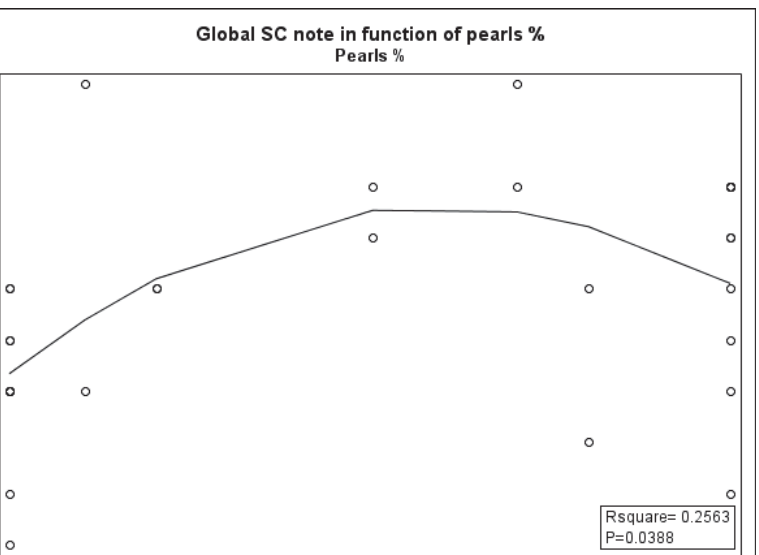
ample, the following chart shows the global note of the SC in function of titanium dioxide %.
he global note is high, more the product is close to the ideal texture. It can go from 0 to10.



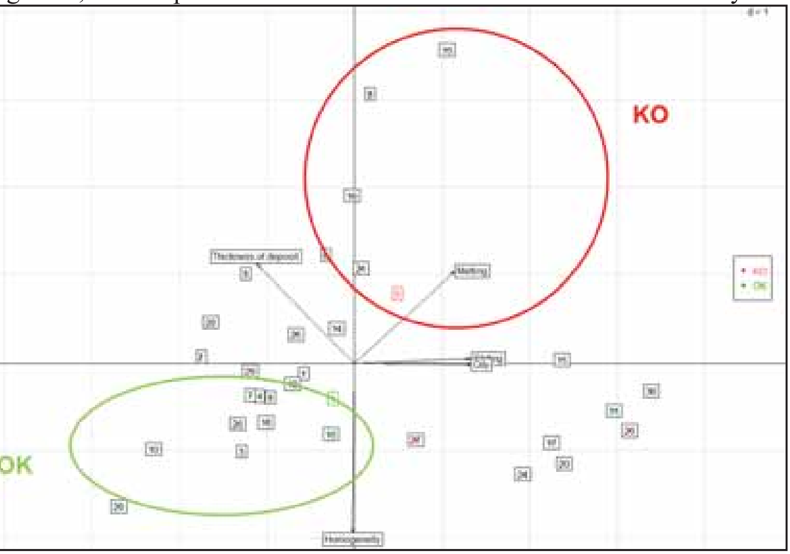
– Global note of sensory characteristic in function of titanium dioxide.

end curve shows that the titanium dioxide % is not in favour of a good value of SC. Thanks to that
f information, we can put in place some limits for formulation.

uare is 0,3615, it means that this chart explains only 36,15% of the global note. In fact, there are
arameters which can play on sensory acceptance of formulas, as pearls (fig 2).



ained sensory panel evaluated the 30 formulas, and give values for 5 different items : Sliding, Melt
ess of deposit, Homogeneity and Oily residue.
ng PCA, we can position the 30 formulas on the same chart as sensory items.



3 – PCA representation of the 5 items which compose the SC and representation of OK in green ,or KO formulas in red.

clusters emerge. OK cluster is close to the homogeneity arrow, it means that OK formulas have, most of high homogeneity values.
ns that KO formulas have higher values of melting. But strongly, we can see that acceptance on SC is a ted to the melting item.

Variable	Model Probf	SC judgement	Average Value	StdErr
Melting	**0.0422**	KO	8.4	0.1
		OK	8.2	0.0
Homogeneity	**0.0087**	KO	5.8	0.2
		OK	6.6	0.2

1 – Melting and homogeneity values of OK and KO groups

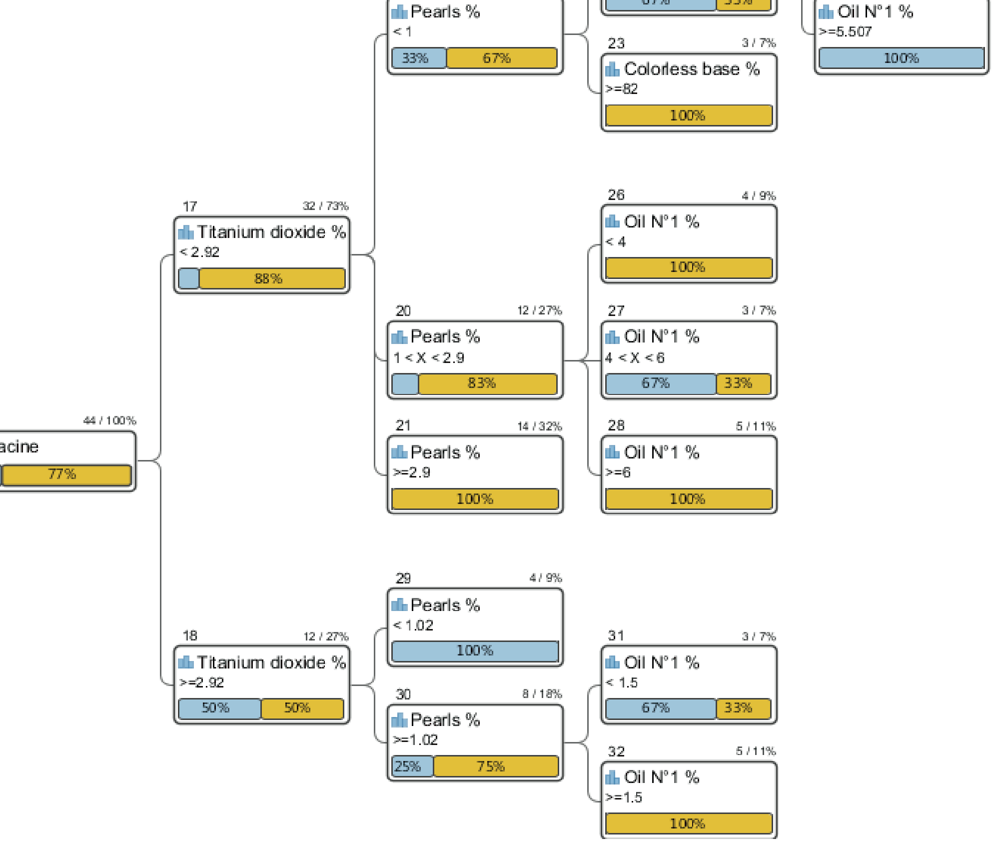
1, we can see that OK group is significantly different from KO group.
s us to better know range values acceptance for each item.

hysical measurements

unately, no physical measurement method was identified to anticipate problems obtaining the SC.

ults Implementation

swer to the main goal of this study, we built decision trees. It helps to draw optimal way for the



4 – Example of a decision tree, built thanks to the 30 formulas

clusion

udy is very rich in data, about formulation, sensory analysis and physical measurement methods. esults are very helpful for better understand our formulation options, including coloring raw als, while still maintaining acceptable texture.

e cases, there is no real solution to obtain the targeted texture. In fact, Titanium dioxide is very ing the texture. When we introduce a high % a titanium dioxide, we have to introduce a pearls um pearl %, and minimum oil N°1 %.

lly, we improve our link knowledge between sensory items and formulation.

nclude that decision trees are very helpful to orient formulation ways.
on trees will be enriched with every new formula of this lipstick range.
tely, they would become increasingly precise.

graphy

cal data sheets of pearls and/or pigments / Sudarshan Chemical Industries
cal data sheets of pearls and/or pigments / Merck

ntroduction

e market of lip products is composed of different types of textures: lipsticks, lipgloss and balms.
e goal of a lipgloss is currently to provide high shine and for some of them, non sticky texture, hence ther
ny different textures in lipgloss on market.
vill be a way of choice for consumers, but the color is definitely the mean to select a product, as it usu
ow last trends.
e color composition permits a lacquered to transparent effect, passing by the pearly iridescent or glittery. T
 challenging factor for consumer's choice, as well as long-lasting or shininess; without forget the qua
ectives, like stability.

order to be very reactive in actual market, R&D laboratories must know very well impact of using the la
ge of pigments and pearls. By analyzing closer each range of lipgloss, it is remarkable that some partic
des show sedimentation (accumulation of solid particles at the bottom of the bottle).
ese particles (here, pigments and pearls) are submitted to gravity and they follow the Stokes law.

$$v = \frac{2\,r^2\,g\,\Delta(\rho)}{9\,\eta}$$

h

- v, fall limit speed (m/s) ;
- r, sphere radius (m) ;
- g, gravity acceleration (m/s²) ;
- $\Delta(\rho) = \rho_p - \rho_f$, difference between the particle and the fluid densities (kg/m³)
- η, dynamic viscosity of the fluid(en Pa.s).

s physical phenomenon is therefore related to the density of each solid particle, but also to the viscosity of
gloss.
 it is necessary to take into consideration these 2 factors.
order to better understand why some shades are concerned, 3 ranges of lipgloss, with 3 different textures
3 different make up results,were studied.
or composition of each range was analyzed, with a special focus on pearls (main particles) and in a sec
e, the white base compositions were studied.
s difficult to characterize a lipgloss' dynamic viscosity as bulks are very heavy and subject to contain bubb
ch can cause trouble in measurement. Dynamic viscosity can be assimilated to rheological behavior.
is latter can be shortened by considering firmness and stickiness measurements, using a texture analy
ipped with a probe which registers resistance to penetration.

laterials and methods

Analysis of color composition

h existing shade of the 3 lipgloss range was listed. The colored raw materials were studied. As the m
ored raw materials are pearls in these ranges, they were studied separately by considering:

- Nature of pearls
- % of same nature of pearls

n the beaker to the pot.
finished products, the filling was realized at 70°C by hand, using a syringe, which mimic indust ditions of packaging.
e cooling down was controlled in the same conditions for each formulae.

.Physico-chemistry

e firmness and stickiness were measured by a texture analyzer (mettre la ref du texturomètre et la sonde)
ch result is obtained by averaging 3 measurements, having verified that the standard deviation between thes asurements is correct.
ese manipulations were made at 2 different deadlines (day of filling +1 and day of filling + 1 month), in or heck there were no variations over time.

.Stability

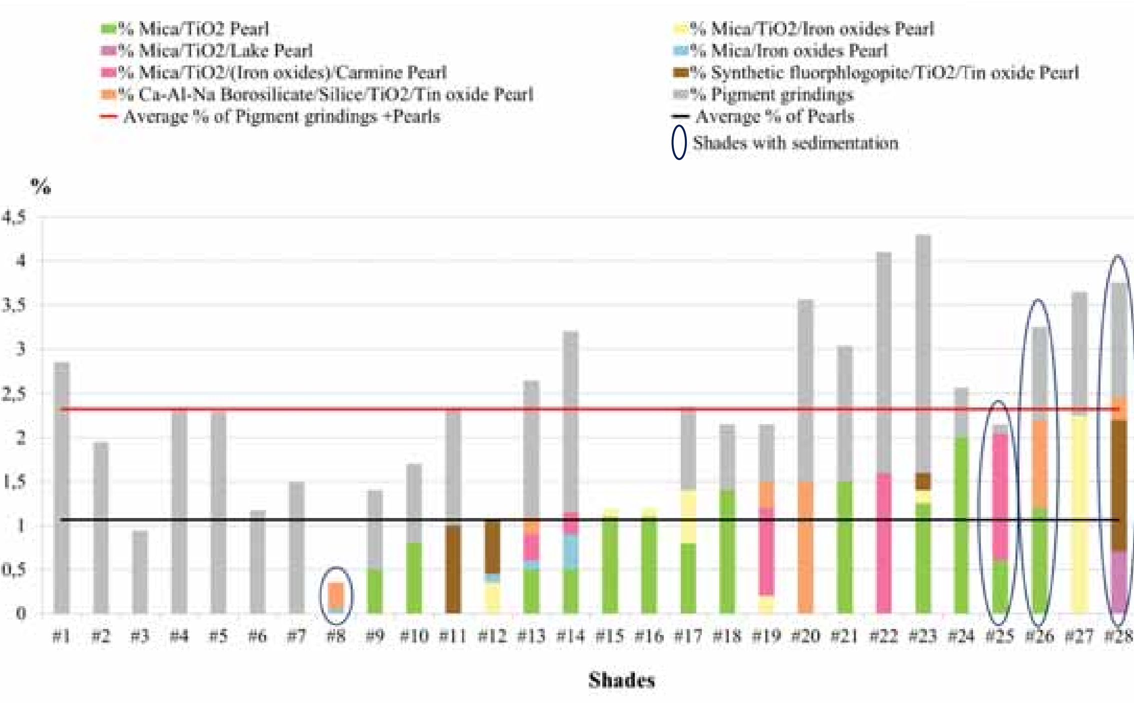
ch formula was submitted into pots and final packaging to different temperatures over time, to control y meet quality requirements imposed by Chanel.

esults

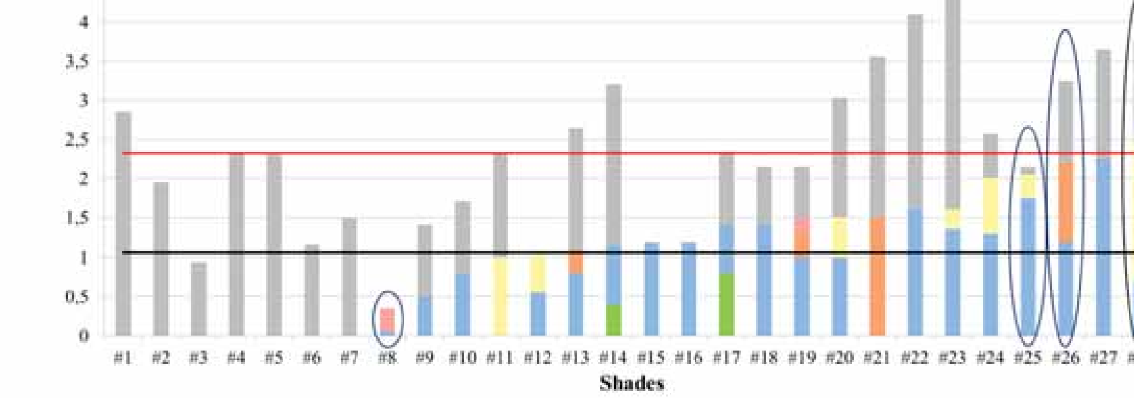
.Analysis of color composition of lipgloss' ranges of shades

order to visualize if there is some commonalities between the identified shades which show sedimentation, or composition of each shade is broken down.
e bigger part is the pearly part. So, pearls were separated by nature and by size.

range N°1, the following charts are obtained.



re 1: Color composition of lipgloss range N°1, by nature of pearls



re 2: Color composition of lipgloss range N°1, by size of pearls.

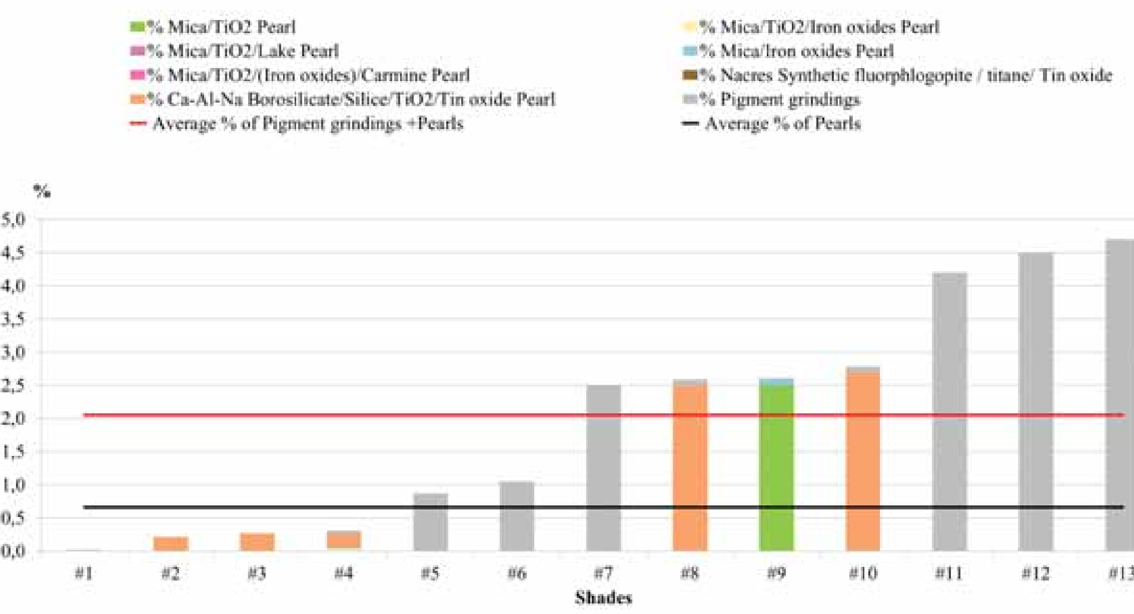
ange N°1, there are 4 shades which reveal sedimentation. There are no commonalities between these ones ns of nature of pearls.

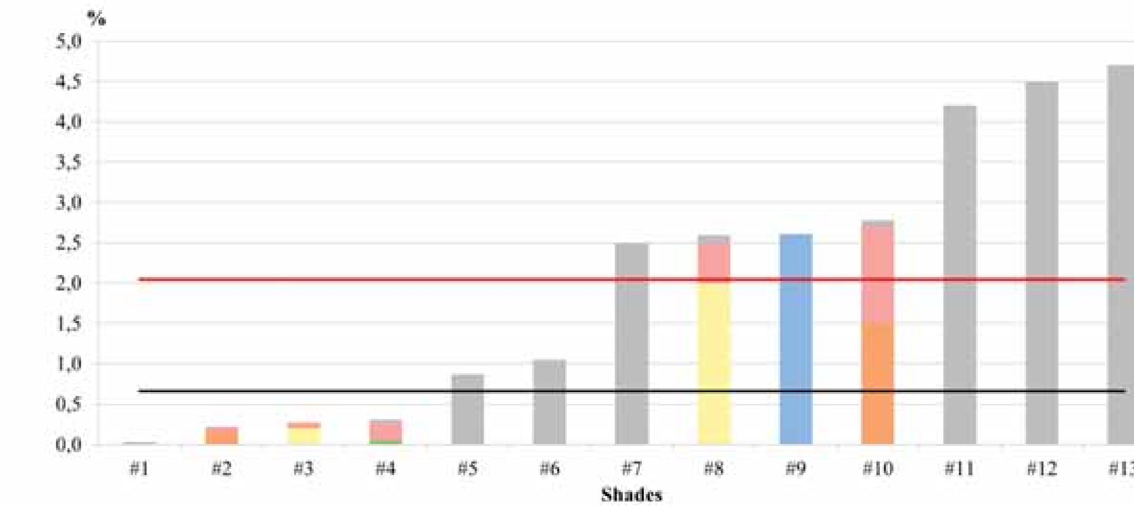
f the 4 shades are among the most "charged". It lead to conclude that up to 2% of pearls, there is a risk imentation.

de #8 contains mostly pearls with a large particle size (95µm). The sedimentation in this one can lained by the absence of pigments, which let become sedimentation more visible in a transparent packag reover, as Stokes law tell us, a larger particle will fall faster than a small one. That is why shade # cerned.

s important to notice that pearls can be white and used for its iridescence. This type of pearls brings less c ensity. In fact, they let sedimentation more visible too.

range N°2, the following charts are obtained.





re 4: Color composition of lipgloss range N°2, by size of pearls.

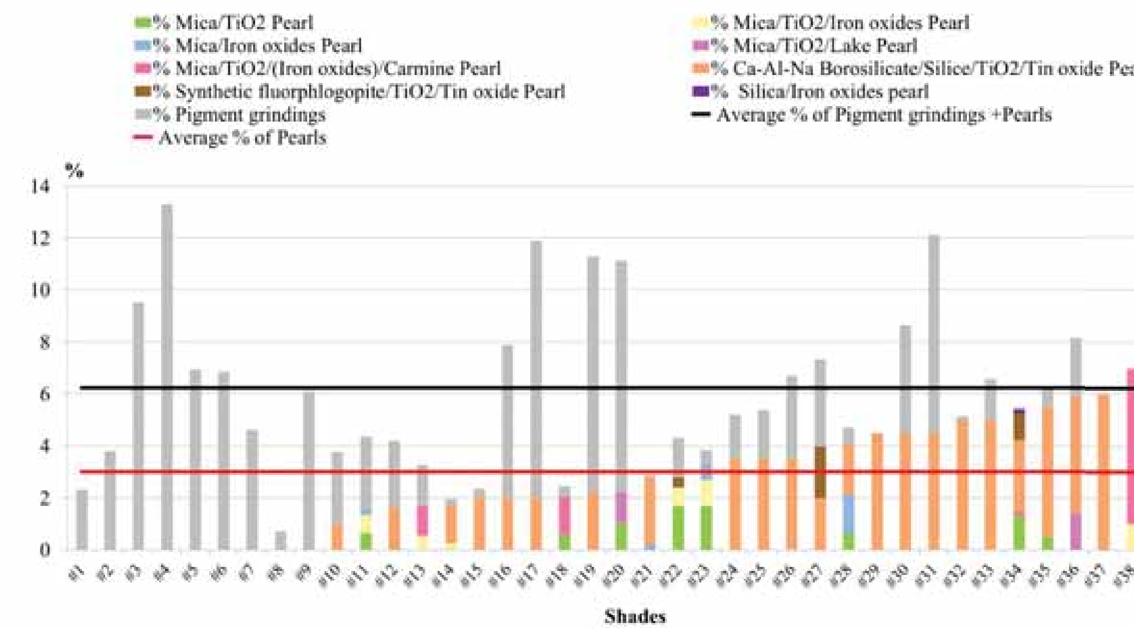
ange N°2, there are no shades concerned by sedimentation.

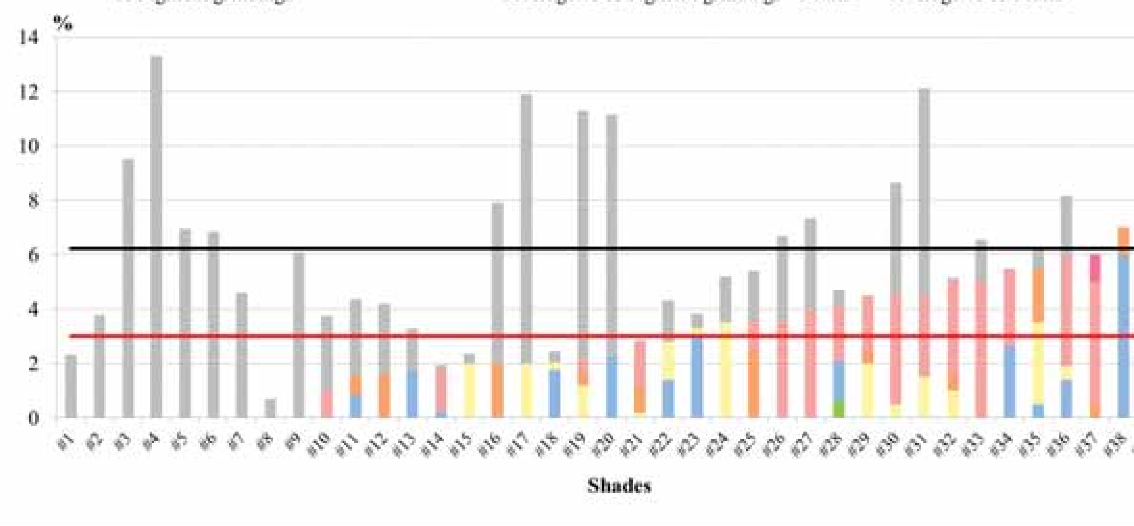
can distinguish 2 shades profiles. The first one is characterized by the absence of pearls (#1, #5 to #7 to #13), the second one shows shades with almost only pearls (#2 to #4 and #8 to #10).

s formula type is used for some particular shades like "fruit-syrup" shades and transparent shades v points, as white base is very transparent.

ntrary to range N°1, each particle size can be used, even in high percentage, without revealing sedimentat nks to very different composition of the white base.

range N°3, the following charts are obtained.





re 6: Color composition of lipgloss range N°3, by size of pearls.

ange N°3, there are no shades concerned by sedimentation.
s range contains shades with more pigment grindings and pearls as the average "total charge" is 6,2
ntrary to 2,33% for range N°1 and 2,05% for range N°2); and the average of pearls is 3,01% (1,06% for ra
1 and 0,66% for range N°2).
s range has shades with almost 10% of pearls.
s very different from the two other ranges, thanks to the composition of the white base.
e sensory feeling is very different too.

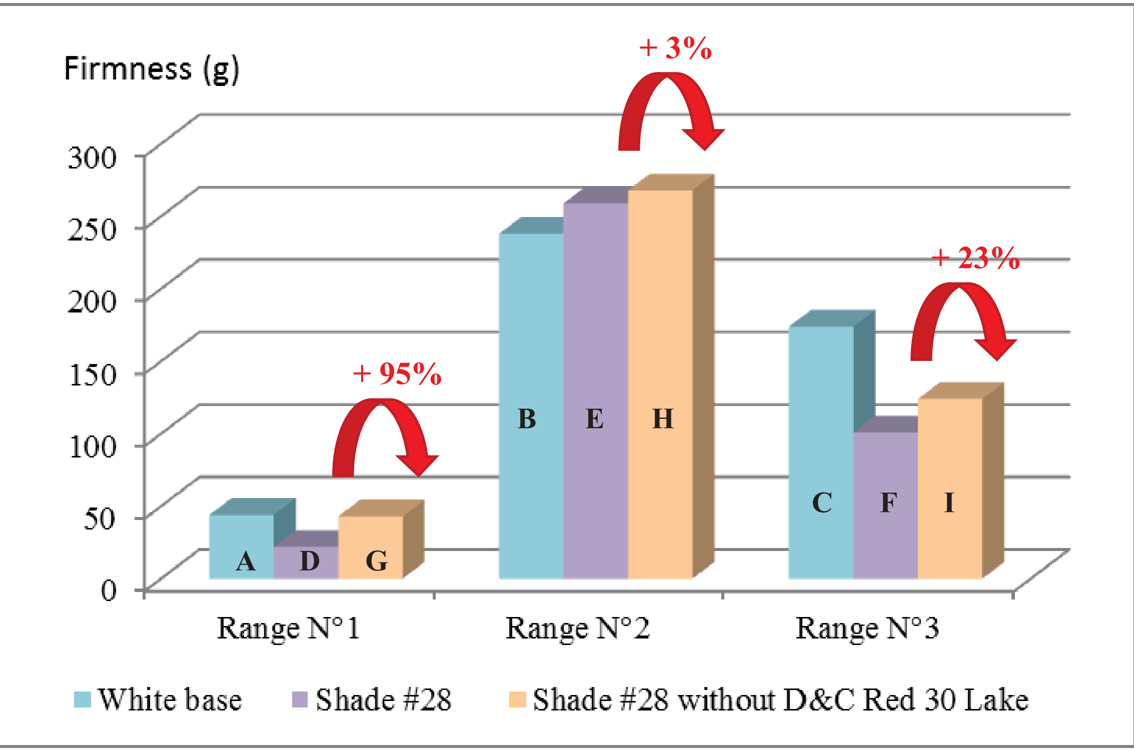
s is the main interest of creating different ranges and different textures. Each of them has its own benefits.

seen previously, some shades have sedimentation. But the impact of the white base is significant.
reover, shade#26 in range N°1 has been reformulated in 2010 as it had a very high sedimentation. The r
mula is D&C Red 30 Lake free.
ce the reformulation, no sedimentation has been noticed.
ade #28 of range N°1 also contains D&C Red 30 Lake.
order to understand impact of this pigment on each lipgloss range, rheological behavior has been studied.

.Physico-chemistry and rheological behavior of each range

order to better understand limits of each lipgloss range, measurements of firmness and stickiness has b
ized on 9 formulas.

	White base of range N°	Shade #28	Shade #28 without D& Red 30 Lake
Formula A	1		
Formula B	1	x	
Formula C	1		x
Formula D	2		
Formula E	2	x	
Formula F	2		x



re 7: Firmness (g) day+1 after filling.

ese measurements show firmness differences between the 3 ranges.
garding variations between A, B and C, range N°1 is largely softer than the two others.
s due to a very different way of formulation during the development of this lipgloss range.
e sensorial positioning was wanted clearly different from the existing ones.

alizing shade #28 in each range has not the same impact on firmness (D, E and F).
 ranges N°1 and N°3, applying this color composition causes a firmness decrease while a firmn
gmentation is observed in range N°2.

moving D&C Red 30 Lake from shade #28 lead to a firmness augmentation whatever the range used, bu
ferent scale.
eed, for range N°2, augmentation is about + 3%. It is important to notice that is below the significa
eshold (5%).
 range N°3, the decrease is more important (23%), and for range N°4, impact is considerable as formula G
rly twice firmer than formula D.

Discussion

 their physic-chemical properties, colored raw materials can impact physic-chemistry of formulas in wh
y are introduced.
, as seen previously, it can be in very different ways.

he raw materials can also be problem other source, like D&C Red 30 Lake.
s pigment is impacting on the firmness of soft products, but much less on more consistent formulas.
en the firmness value is high, the flexibility acceptance on a decrease or increase will be larger than when
nness value is low.

e ideal formula, in terms of quality requirements, would be very firm, in order to not be subjected to co
nposition (no sedimentation, no impacting softening).
fortunately, almost of the time, it is conflicting with a pleasant, non-sticky and easily applicable texture.
often, formulation is a compromise history.

Conclusion

e goal of this study is to better understand impact of colored raw materials in each existing Chanel lipgl
ge, in order to prevent physical phenomenon like sedimentation.
ne impacting parameters/raw materials have been identified as troublemakers.

yond it, it is important not to conclude prematurely and to apply these conclusions on every product.
s, these parameters are impactful; but in unequal proportions depending on the product, so depending on
te base used.
irmer lipgloss will allow more freedom of color formulation, but may have sensorial constraints as a hea
ture or a sticky effect.
netimes, requests are difficult to meet, as they are linked to physics law.
ery white base is designed to answer to a marketing brief in terms of shades, but also in terms of senso
file.
e objective is now to find to way to have both of them.

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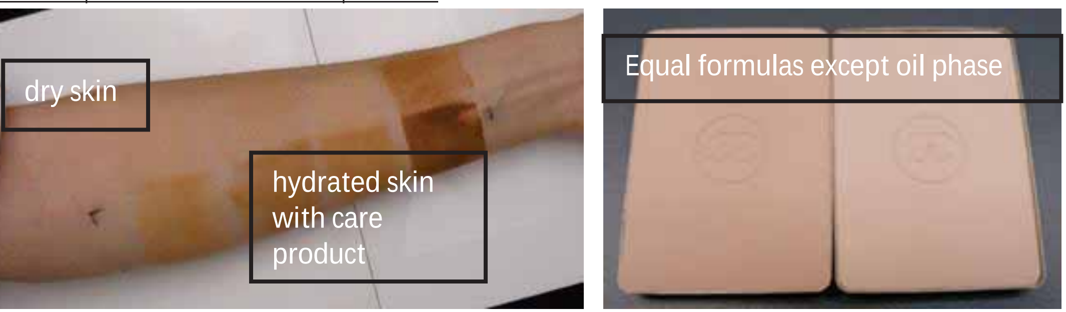
[7] Technical data sheets of pearls and/or pigments / BASF Corporation
[8] Technical data sheets of pearls and/or pigments / Kobo Products
[9] Technical data sheets of pearls and/or pigments / Hebei Oxen Special Chemical
[10] Technical data sheets of pearls and/or pigments / Eckart GMBH

ntroduction

mpact powders such as foundations are complex compositions made of a blending of white powders (mine anic or synthetic), pigments (mineral or organic) and oil phase (esters, surfactants, silicones…). Ratio ween those 3 phases must be respected to make sure that, once pressed, the whole is cohesive and dusty ugh to be taken. Criteria for choosing them depend on the final product expectations. In this way, the prod ld answer claims such as: specific texture, comfort and lasting on the skin or UV protection but mostly col al color is obtained by the pigments and the capacity of the oil phase to wet them and so to develop their uration. Also such color must be the same between what the consumer sees on the pan (mass tone) and wha applies and keeps all day on her skin (skin tone). Yet, experience and observations underline an issue whi sisting of the color saturation change, immediate or over time, once the product is applied on the skin. erefore, the goal of this study is to find the best oil phase composition in order to reduce the saturation gap also to understand the quality impacts of this oil phase on the final composition such as strength of the ssed cake and cohesion.

re 1 : example of skin tone and mass tone representation



Methods and materials

e study has been carried out on a composition calls reference formula. The quantity of the above 3 phases i ed as is: 84,7 % of white powders, 8,0 % of pigments, 7,3 of oil phase. Only, the oil phase composition ies, the wetting ingredient represents the entire oil phase. In this way, the variable will allow the screening wetting ingredients including silicones, alkanes, esters, polymers and surfactants. The laboratory procedure nposed by the main steps such as blending, micronization, sieving and pressing. Then each pressed powder racterized to highlight the impact of the oil phase on the color by colorimetric values (L,C,h) but also, on lity parameters like powder coherence (ductility) [1] by rheology and cake strength by drop test. The first asurement is done within the 3 first days after the pressing and/or production; the second measurement is e after 15 days. Those 2 weeks in between allow any shade or texture evolution to be seen. Samples are red 20°C hidden from light during this time.

re 2 :Powder foundation composition:

ZPT 003611 F001 01	CAPRYLIC/CAPRIC TRIGLYCERIDES	1
ZPT 003611 F002 01	OCTYLDODECANOL & BEESWAX	2
ZPT 003611 F003 01	ETHYLHEXYL METHOXYCINNAMATE	3
ZPT 003611 F004 01	DIISOPROPYL SEBACATE	4
ZPT 003611 F005 01	SQUALANE (FROM OLIVE)	5
ZPT 003611 F006 01	HYDROGENATED CASTOR OIL ISOSTEARATE	6
ZPT 003611 F007 01	JOJOBA ESTERS & POLYGLYCERIN-3 & ACACIA DECURRENS FLOWER WAX & HELIANTHUS ANNUUS CERA SEED (HELIANTHUS ANNUUS (SUNFLOWER) SEED WAX)	7
ZPT 003611 F008 01	LACTIC ACID	8
ZPT 003611 F009 01	COCAMIDOPROPYL BETAINE	9
ZPT 003611 F010 01	PEG 10 DIMETHICONE	10
ZPT 003611 F011 01	PVP/HEXADECENE COPOLYMER	11
ZPT 003611 F012 01	DICAPRYLYL CARBONATE	12
ZPT 003611 F013 01	PENTAERYTHRITYL ADIPATE/CAPRATE/CAPRYLATE/HEPTANOATE	13
ZPT 003611 F014 01	DIPENTAERYTHRITYL HEXAHYDROXYSTEARATE/HEXASTEARATE/HEXAROSINATE	14
ZPT 003611 F015 01	OCTYLDODECYL NEOPENTANOATE	15
ZPT 003611 F016 01	POLYHYDROXY STEARIC ACID & LECITHIN & ETHYLHEXYL PALMITATE& ISOPROPYL PALMITATE & ISOSTEARIC ACID & POLYGLYCERYL 3 POLYRICINOLEATE	16
ZPT 003611 F017 01	DIMETHICONE & DIMETHICONE CROSSPOLYMER (85/15)	17
ZPT 003611 F018 01	C 12-15 Alkyl Benzoate	18
ZPT 003611 F019 01	TIO GLYCERYL TRIOCTANOATE	19
ZPT 003611 F020 01	COCONUT ALKANES & DIMETHICONOL	20
ZPT 003611 F021 01	SQUALANE (FROM SUGAR CANE)	21
ZPT 003611 F022 01	POLYGLYCERYL-4 CAMELIATE	22
ZPT 003611 F023 01	DIISOSTEARYL MALATE	23
ZPT 003611 F024 01	ISOPROPYL LAUROYL SARCOSINATE	24
ZPT 003611 F025 01	DIMETHICONE	25

aracterization equipments:

- Color by spectrocolorimeter CM-2600d, KONICA MINOLTA

vitro measurement of the color of the pressed powder surface one day after pressing and 15 days after ssing. Measurement with contact.

- Color by spectrocolorimeter VS450, X-RITE

vivo measurement of the color of the powder applied on the skin arm surface. Measurement without contac

- Coherence by texture analyzer TA.XT Plus, MICROLAB STABLE SYSTEM

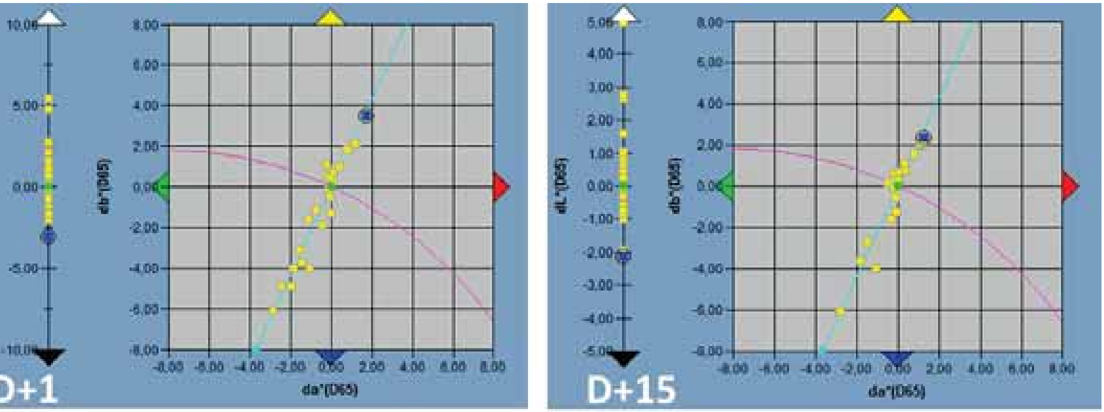
asurement of the coherence 3 days after producing and 15 days after producing

- Strength by drop test, 30 cm high

eelings allow classifying the 25 tested wetting ingredients by the color saturation (C) of the formulated vders.

his way, the CIELab graph below (figure 3) shows that all the trials are aligned along the saturation (C) lin ue line). Color evolution can be explained by the saturation and lightness which are negatively correlated. T ference of the tonality values (h) is not meaningful, indeed its standard deviation is 0.94 between the 25 ues at D+1 and also at D+15 (see chart 2). Also, materials are almost ranked the same way by the saturatio er 1 day and after 15 days (despite missing measurements at D+15). So the composition of the oil phase elops only the intensity of the pigments and it lasts over time for most of the materials.

re 3 : Colorimetric values measurement D+1 and D+15



t 2 : colorimetric values L,C,h , D+1 and D+15

D + 1 measurment			
of the edients	CHROMA SATURATION C*(D65) - D+1	LIGHTNESS L*(D65)	HUE - TONALITY h(D65)
5	23,91	73,99	65,06
15	22,47	75,05	64,65
21	22,43	75,06	64,98
19	22,02	75,91	65,24
25	21,97	75,39	65,52
1	21,23	76,65	65,66
20	21,12	76,24	65,42
4	20,92	77,92	67,09
17	20,88	76,95	65,86
18	20,71	77,25	65,91
3	20,43	77,49	66
12	20,42	77,61	66,4
24	20,4	77,77	65,98
2	19,53	76,48	64,93
22	18,83	76,33	63,77
8	18,67	78,67	65,89
9	18,12	75,88	64,01
7	18,1	79,11	66,37
11	16,58	79,88	65,8
6	16,04	78,2	64,51
10	15,95	77,08	62,72
23	15,59	79,23	65,32

D + 15 measurment			
n° of the ingredients	CHROMA SATURATION C*(D65) - D+15	LIGHTNESS L*(D65)	HUE TONALITY h(D65)
5	22,65	74,98	64,92
15	22,34	75,16	64,57
21	22,31	75,16	64,95
19	21,75	76,25	65,23
1	21,1	76,92	65,77
20	20,87	76,5	65,37
18	20,69	77,33	65,94
12	20,48	77,88	66,43
17	20,31	77,16	65,55
3	20,26	77,68	66,02
4	19,93	78,68	66,83
24	19,91	78,13	65,88
2	19,45	76,77	64,9
22	18,84	76,38	63,94
9	18,41	76,08	64,22
11	16,94	79,74	66,1
23	15,98	79,86	65,79
10	15,96	77,53	62,89
16	13,33	82,05	65,51

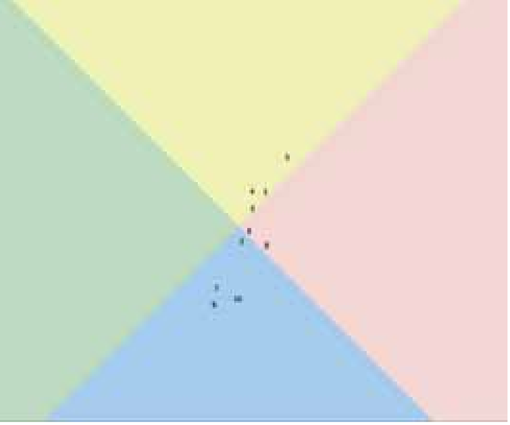
e Top 5 materials arelisted as below :

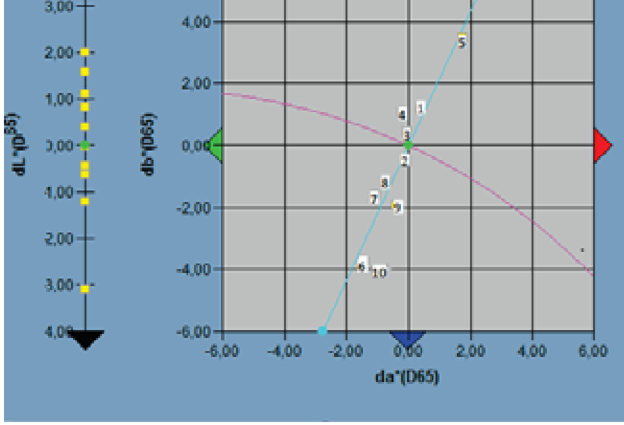
TURATION RANKINK OF THE INGREDIENT FOR BOTH MATURITIES
QUALANE from olive oil, material n°5
OCTYLDODECYL NEOPENTANOATE, material n°15
QUALANE from sugar cane, material n°21
TIO GLYCERYL TRIOCTANOATE, material n°19
DIMETHICONE, material n°25 or CAPRYLIC:CAPRIC TRIGLYCERIDES, material n°1

fferences are optically perceptible, see the picture 4 below, for instance, trial n°5, 15 and 21 are clearly mor
ense.

re 4 : mass tone color differences :

e initial postulate consists on considering that the mass tone on the pan will be the reference of the study. It ans our hypothesis is based on the fact that the more intense is the mass tone, the highest color developmen have. A in vivo method of color measurement (skin tone) comes to rely on the mass tone observations. As ure 5 shows, the tendency for the in vivo measurement is the same than in vitro, indeed the values go along saturation line. Also, the ranking of the trial is the same, its means the impact of the wetting ingredients do change once the product is applied, for example trial with SQUALANE is still the most intense.

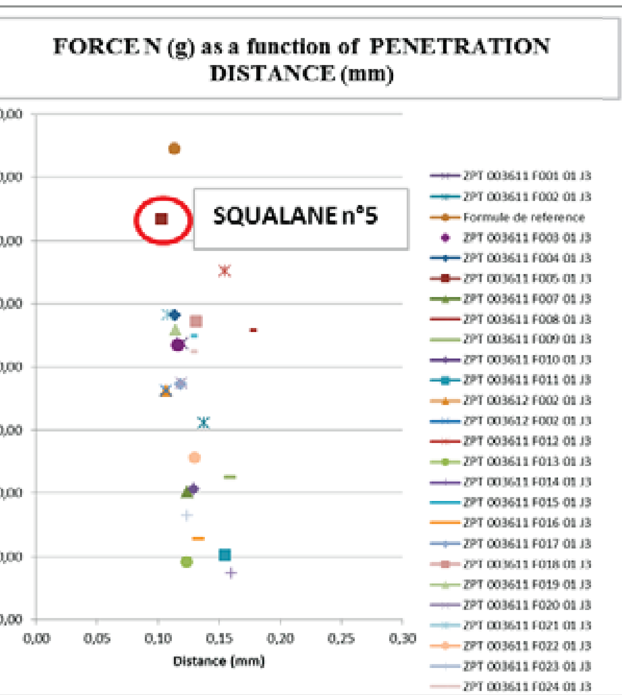


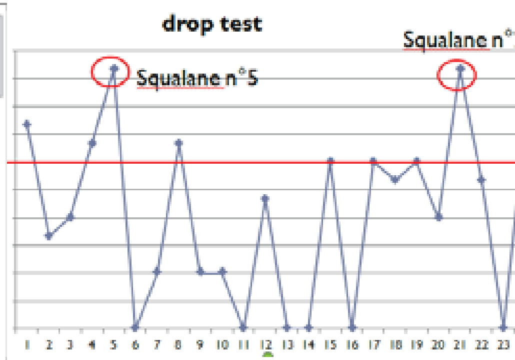


. Result on foundation quality parameters

e study shows the powder composition with SQUALANE, has the highest cohesion. Indeed, in figure 6, the
l with squalane (n°5) is the most resistant against a normal force, it breaks under around 65 grs (knowing t
is the our standard limit for a good cohesion). Also, trials with squalane (n°5 and n°21) are the strongest
inst shocks. It is the wetting ingredient that reduces the less the cake strenght and it is above the red line o
ps which represents the quality standart for a normal use.

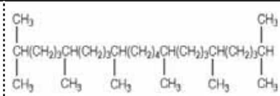
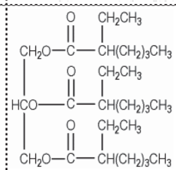
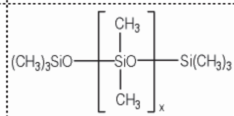
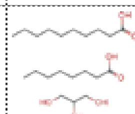
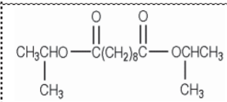
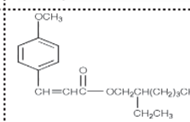
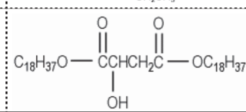
re 6 : coherence by ductility analysis and strength by drop test.





ting agent does not have the worse result on saturation. No real correlation has been really found between mical and the saturation even if the top five on saturation are very fluid oils. Indeed the chart n°3 shows th 5 on saturation and 3 others in the middle and at the end of the ranking. It is clear to see no group of mical family, e.g. esters can be good wetting (rank 2) and less (good rank 22), no group of chemical struct her viscosity nor molecular weight. But one material (squalane) tends to be very different; it is the only rocarbons and it is the best wetting agent in our ranking.

t 3 : material chemical composition and viscosity [2] [3] [4] [5] [6] [7] [8] [9]

ank and 3	**SQUALANE** material n°5 and n°21	**HYDROCARBONES** Squalane is the saturated branched chain hydrocarbon	$C_{30}H_{62}$	34 mPa/s (T=20°C)	
ank 2	**OCTYLDODECYL NEOPENTANOATE** material n°15	**ESTERS** Octyldodecyl Neopentanoate is the ester of Octyldodecanol and neopentanoic acid	$C_{25}H_{50}O_2$	20 mPa/s (T=25°C)	
ank 4	**TIO GLYCERYL TRIOCTANOATE (TRIETHYLHEXANOIN)** material n°19	**FATS AND OILS** Triethylhexanoin is the triester of glycerin and 2-ethylhexanoic acid	$C_{27}H_{50}O_6$	28-34 mPa/s (T=25°C)	
ank 5	**DIMETHICONE** material n°25	**SILOXANES AND SILANES** Dimethicone is a mixture of fully methylated linear siloxane polymers end blocked with trimethylsiloxy units	$(C_2H_6OSi)_xC_4H_{12}Si$	5 mPa/s (T=20°C)	
ank 6	**CAPRYLIC/CAPRIC TRIGLYCERIDE** material n°1	**FATS AND OILS** Caprylic/Capric Triglyceride is the mixed triester of glycerin and caprylic and capric acids		27-33 mPa/s (T=20°C)	
ank 8	**DIISOPROPYL SEBACATE** material n°4	**ESTERS** Diisopropyl Sebacate is the diester of isopropyl alcohol and Sebacic Acid	$C_{16}H_{30}O_4$	6,9 mPa/s (T=25°C)	
ank 11	**ETHYLHEXYL METHOXICCINAMATE** material n°3	**ESTERS** Ethylhexyl Methoxycinnamate is the ester of 2-ethylhexyl alcohol and methoxycinnamic acid	$C_{18}H_{26}O_3$	99,8 mPa/s (T=20°C)	
ank 22	**DIISOSTEARYL MALATE** material n°23	**ESTERS** Diisostearyl Malate is the diester of Isostearyl Alcohol and Malic Acid.	$C_{40}H_{78}O_5$	1500-2000 mPa/s (T=30°C)	

ally, this best candidate has been tested on other compositions, different from the reference formula (see re 7). Such trials confirm the efficiency of the SQUALANE on the color saturation.

re 7 : Tested on in house product named here for the study oil control foundation

saturation gap between the mass tone and the skin tone. However it is more difficult to find a clear relation between the chemical structure and the capacity to wet the pigments. At least, the tested ingredient not have the same capacity to wet pigments and so to develop color of the final composition.

e study shows also that never one impact appears by itself, it is combined with others. Indeed, a chemical ucture can change the saturation, the cohesion and the strength of a pressed composition. In this way it can ed those 3 characteristics are correlated and depend on the oil phase composition.

oliography

Hélène de Clermont Galerande Chanel R&T, Alexandra Barré ENSCBP Bordeaux, Patrick Snabre CNRS Bordeaux, Ageing And ility Of Loose Powdered Cosmetic Preparations: Influence Upon Compaction And Fracture Resistance Of Pressed Tab, IFSCC, Paris ober 2014
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Effect of Color in monitoring and controlling water consumption

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1. Abstract

Water is our most precious and natural resource and there are a lot of methods to apply pervasive way for decline the water wastage in private places. Results show that, recommendation and force are not effective for initiating a desired change in user behavior, so if we apply the situation that effect on people `s life and raising awareness indirectly, then we would success to change user behavior in a true way.

Color as a natural factor that affect the human life in many different aspects , can change the behavior and even the characteristic of the people. It is proved that color-trophy is one of the useful ways for psychological and physical treatment.
Each color makes different reaction and feeling in the body, by recognition the meaning of each color and its effect, can apply it in many parts of the life even in changing of the behavior.

This paper presents a new approach for changing human behavior in the use of water.
By applying the color is tried to motivate immediate reduction in monitoring and controlling water consumption .

Keywords

User behaviour , methods , persuasive way , water consumption, color effects

2. Interduction

Societies are currently facing a number of crucial problems . Here we focus on global water Shortage that are reflecting on human's future life.
As we know Water is used for a wide variety of things in the modern world. It's used in large quantities in agriculture and livestock production, to generate electricity in thermo-electric power plants, and in numerous industrial processes.
Unfortunately, most of economic crisis is made by human indirectly.
human by produce and apply unqualified materiel and doing some incorrect behaviors increase these problems so one of the useful solution to control it is achieved by changing some incorrect routines and habits.

Energy conservation and governmental agencies have tried to make people conscious about the implications of wasteful behavior,and by this knowledge try to change these habits but their efforts have had little or no effect upon behavior.

What is an effective way to change incorrect behavior? People eat unhealthily, people drive unsafely, people irritatingly hang around at specific places, or people do not pay for their train tickets.

Social problems are complex phenomena that are often discussed in. They are understood and explained by different fields such as psychological,cultural, sociology, and political processes.

Nynke Tromp an expert in social design and behavior believed that,the product that made for changing user manner, distinguish four types of influence on user behavior.
Coercive, persuasive, seductive and decisive method.
While Coercive way creates a perceivable barrier for undesired behavior such as pain, shame and make the behavior a necessary activity,Persuasive way provides the user with objective information about the consequences of certain behavior. Like the cigarette package also in this method, it can trigger different motivations for the same behavior by adding an extra function to the product like, Illustrating the garbage bin along the highway is designed as a basket used in sports to score. A seductive method also elicits emotions to trigger action tendencies or activate physiological processes induce behavior. In Decisive way make the desired behavior the only possible behavior to perform like, Supermarkets make narrow aisles so that customers cannot easily talk to each other and must focus on the products instead .[2]

According to mentioned methods, indirect and hidden techniques like,Persuasive way can be employed to effect sustained behavior change that users take with them beyond the point of interaction .Also, this technique such as reminders have been shown to be effective in reducing water consumption at home.

So ambient persuasive displays could be a potential way to raise awareness and lower the energy consumption in private households. There already exists a range of products in this direction. However, none of them seem to have any long term persuasive effects [14].

The main aim of this study is by applying of the color effect on household water consumer behavior.

3. Color Effect

Color same as music use as a common language and carry specific meaning and convey specific information so color understand by same meaning with the people such as white of the flag by meaning of peace.

Light and color also effect on people's decisions and emotion like, positivity sense that will be much in a sunny day in comparing with a foggy time.
The magical properties of light and color, granted by men since the earliest of times.[4]
research indicates that color often serves a signal function for animals, facilitating fitness-relevant behavior [10].
Johnnes Ittens in his book say that blue light can effect on flies and attract more files surrounds of this place in other research discovered that red color can make the stress in gold fish [9].
colors and light even effect on greens and tree .Color can effect on size of something blue and green color seems larger than red and yellow. And also red and yellow appear closer than blue and green.this effect also can be on temperature feeling, hardness and weight of the things.

Furthermore, several experiments have shown that different colors affect blood pressure, pulse and respiration rates as well as brain activity and biorhythms. As a result, chemotherapy is now called photo biology or color therapy are now used colors in the treatment of a variety of diseases.
Within the past decade, for instance, baths of blue light have replaced blood transfusions as the standard treatment for about 30,000 premature babies born each year with potentially fatal neonatal jaundice. Further, because the blue light irritates nurses working in these wards, many hospitals have added gold lamps to soothe their staffs.

Thus colors are an important part of our sensations [15]they had a direct physiological impact. The electromagnetic energy of color, interacts in some still unknown way with the pituitary and pineal glands and the hypothalamus, deep in the brain, These organs regulate the endocrine system, which controls many basic body functions and emotional responses, such as aggression.
As we know Blue of water,brown of a bear, green of leaves,amber of sunrise and sunset [6] are colors that share common meaning among a lot of people.[5] but both connections between colors and emotions probably have at least three sources: evolution,culture, and personal experience.
For example, to determine whether a specific red that indicate as a danger or failure generated by teachers' use of red to mark errors in our childhood or whether the biologically based predisposition to interpret red as a danger signal in competitive contexts is sufficient in and of itself[11].
Its not matter what made us to have this feeling by colors the matter is that the influence of color on psychological functioning is Undeniably.

It hypothesized , color in nature that signal danger will increase the physiological variables like heart rate, brain activity, and retinal focus. Whereas the colors in nature that are non-threatening will decrease the heart rate, brain activity, and retinal focus or produce no changes.[7]
some colors send an "approach" signal while others send an "avoid" signal [13] in figure 1 Yan Xue show the effect of main color on emotion.

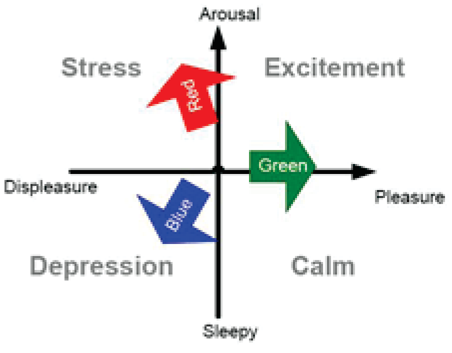

Fig. 1 - Yan Xue color distribution

4. Using color in changing behaviour

In general, sociology-demographic factors such as ex,age,education,social status, Income are not enough to predictors and change of ecological behavior some psychological variables also can ex-plain the behavior of the ecological consumer.happiness,Stress,..and effect on people's consumption.
As we mentioned above,Color effect on psychological functioning and eliciting emotions from the user.
Industry also uses color mostly in many signs and indicators to transfer the emotional message, for example red color mostly use as a sign of alarm, danger,emergency or stop,we also use yellow the sign of toxicity material box.
Recently colors are considered in many fields of industry.
Elevator designers place the numerals and floor indicator lights over people' s heads so that they avoid eye contact and feel less crowded.
The architect also applied color to control a crime in the society, they said that the use of yellow street lighting "can increase the crime rate in comparing with white lighting.Also use of blue lighting in public toilets.[1]
Another study indicated that people walked faster down a hallway painted red or orange than down one painted in cooler colors.

According to the mentioned items,Color and light recently are applied to effect on people’s behavior by using some products.
for use of color to change behaviour we need to understand which emotions there are and how it should be presented to the user, in such a way can apply them.

5. Color and Water consumption.

As we know there are lots of ways to persuade people for using less water. Here we emphasize on household water wastage and a concept which may persuade people to save water at home indirectly.

Many of the behaviors that lead to wasting water occur at sinks in the home, people leaving the water running while brushing their teeth, washing dishes, etc.
By reforming person’s behaviors of everyday using water, we can improve safety and performance as well as motivating water conservation.

There are not many serious projects which consider using of colors to peolpe’s behavior in this matter. We have 2 projects which have focused on using colors in result of practical solution.

The first one is HeatSink that expresses the value and status of water by illuminating the stream with colored lights to communicate its temperature and provide useful information about the temperature of the water without altering the function of the sink. Colored LEDs mounted around the faucet aerator are driven by a PIC microprocessor to illuminate the stream of water, red when it is hot and blue when it is cold [3].This product coming in figure 2.

The second one is a Traffic Light Water Awareness. It is Installed on household faucets to motivate people to turn off the tap when the water is used more than normal target point. This is happening by giving the user positive feedback and reminders while using the sink and when closing the tap.

Terrific light is consists of 3 affective colors (green,yellow,red) which more than metaphorical issue use 3 different colors effect. Each color has specific meaning and persuade most consumers to act different behavior in front of it.
Green was selected as the chromatic contrast to red,and carry the approach meaning of “go” in contrast to red by the meaning of “stop” in traffic lights.
Because red and green are considered opposite colors in several well-established color models [12] Actually, while green color is on, it means consumer use the best amount of water and while it becames yellow it means the usage of water is on a moderate rate. Red color alarms over usages than colors like green and yellow. Made the consumer alarm that the usage of water is more than deter mined amount and aware the user need to do an action and close the tap. This concept can set for any standard and water normal usage according to

people culture and geographical area. As well as this project can be equiped with more functions to persuade people in closing tap by adding simple programme to PLC example, after red color initiate, the tap automatically close or made an alarming sound. Even it can be equiped for different task in front of the sink. Figure 3 shows this product.

Figure 2 have led participants to effect on their behaviors and reconsider sustainability and environmental issues beyond water usage and alarming by use of colors and light. [16]

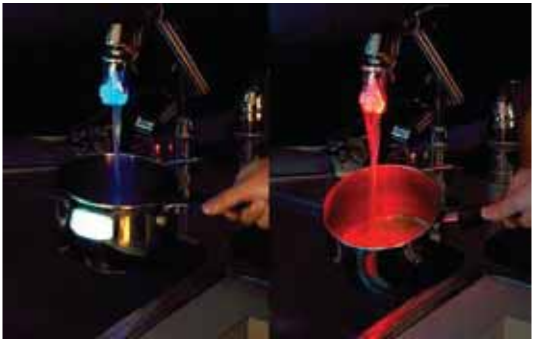

Fig. 2 - HeatSink illuminates the stream of water according to its temperature, becoming red when hot and blue when cold.

Fig. 3 - Teraffic Light water awareness

6. Conclusion.

Colors are an important source of information for many people, they influence on our decisions based on what we see and interpret them.

The color effect on people life can be originated by their culture or psychology issue. but at last the total understanding of color mostly common between people.
these similarities made emotions and sense that can lead to make product and changing behaviors. This usaully influences unconsciously and indirect.
Here we mentioned some projects which have been done recently in water consumption by using of color affects. We hope to use color motivation methods establish a prevalent way in water conservation studies and without one's conscious awareness , encourage users to use less water .

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7. COLOUR AND CULTURE

Ground *lapis lazuli*. A new approach to the history of the colour term 'azure' and the pigment *ultramarine blue* up to the 13th Century.

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1. Introduction

The present paper aims to explore the main aspects of the social history of ground *lapis lazuli* and the pigment *ultramarine blue* up to the end of the 13th Century.
Since the first scientific work on *ultramarine* in 1792 by Johann Beckmann [1], the phrase *lapis lazuli* and the word *ultramarine* seemed strange. *Lapis lazuli* is in fact an odd mixture of the Medieval Latin word for stone (*lapis*) and *lazuli*, which is a loanword from the Persian *lājvard* (*lâzhvard*; *lâzvard*), via the Arabic *lāzaward* and the medieval genitive of the Latin *lazulum*. According to its modern meaning, *lapis lazuli* indicates the rock, whose major component is the blue mineral *lazurite*; while *ultramarine blue* refers to the pigment obtained by crushing and grinding the *lapis*, successively enriched by the blue mineral *lazurite* via a floatation process.
Ultramarine blue is the English translation of *ultramarine azure*, a medieval phrase which is itself misleading in many ways. Firstly, neither *lapis lazuli* nor *ultramarine blue* originate from the "the opposite shore of the sea", as the medieval name, *ultramarine,* suggests, but have more distant origins. Ground *lazurite* was at least used since the 4th Century AD as a wall pigment in Central Asian caves devoted to Buddhist rituals (Kizil grottoes). The mineral deposits of the Pamir Mountains in Tajikistan, the Chagai Hills in Pakistan and in Afghanistan are the likely sources of the mineral *lapis* [2]. Secondly, the medieval term 'azure', as a *denotatum* of a visual percept (colour term) or used both for denoting the rock *lapis* and the pigment *ultramarine*, was successively substituted in many European languages by the term 'blue', which became a "basic colour term" (hereafter BCT) [3; 4].
After the publication of a reference paper by Joyce Plesters [5], new analytical, non-invasive and in *situ* techniques were introduced for detecting the presence of *lazurite*. In this way, increasing data was available to scholars. However, the history of *ultramarine blue* continues to be discussed within a framework that considers the art of painting but ignores other utilisations of ground *lapis* for medical preparations, preparing inks, colouring glass enamels, and pottery glazing. Similarly, the complex history of the medieval family of words deriving from the Persian word *lājvard* has barely been touched upon.
The present paper has a twofold approach. On the one hand, we examine the use of the *ultramarine blue* on various supports and analyse the first medieval recipes for achieving *ultramarine*. On the other hand, we will record the classical and medieval words for blue pigments and colour terms of 'blue' as a BCT.
While this paper is in large measure based upon previous research, we have been able to add a few bits of new information, which have not yet been published. Because we are touching on a large number of topics, we will address them schematically, for which we apologise. However, our main aim is to present a new approach to the issue.

2.1. Some of the social uses of ground *lapis lazuli* outside the art of painting

Specific geological and geochemical conditions are required for the petrological genesis of the *lapis*, and for that reason there are only a small number of deposits around the world. There is evidence that not only the quarries of Badakhshan in north-eastern Afghanistan, but also those of Pamir Mountains in Tajikistan and the Chagai Hills in Pakistan, were being exploited since ancient times, thus refuting the hypothesis of a single supply source [2].

Lapis lazuli's presence had been detected in almost all major archaeological sites from Egypt to central Asia. It was first attested around at the 7000 years BC in Western Pakistan [6]. In Egypt, it had been used since the early pre-dynastic Egyptian period for beads and inlays (Naqada I period, 4000-3500 BC) and subsequently for amulets, jewellery and seals [7]. Archaeological evidence shows that *lapis lazuli* was generally extracted with most of the calcareous matrix removed. The process of extracting *lazurite* from *lapis lazuli* for producing beads or carved objects involves simple utensils and repeated smoothing, incising and chipping. Both in Mesopotamia and Egypt, *lapis lazuli* was highly valued by the ruling classes, who referred to the stone in their respective mythologies and religious stories [6; 8].

Many pieces of evidence show that ground *lapis* was used long before the Western Medieval uses of *ultramarine* on walls and manuscripts. However, being that the present work is limited to a small number of pages, we will only summarise the topic. The most important use of ground *lapis* was its medical use. The two main examples referred to in Egyptian and Mesopotamian medical pharmacopeia are the eye ointments in Ebers' papyrus (around 1550 BC) [9] and some written records in the 7th Century BC Ashurbanipal library [10].

Ground *lapis* is present in the vast Islamic medical literature and in the *aqrābādhīn* or recipe-books for the composition, preparation and application of various drugs. From *Ḥunain ibn Isḥâq* (809-877) to the late 13th Century pharmacist al-Kūhīn al-ʿAttạ̄r, and his formulary *Minhāj al-dukkān,* there are a long series of authors, who refer to *lapis* as a regular component of the Islamic medical preparations.

At least two factors were determinants of the systematic use of ground *lapis* in the Islamic pharmacopeia: i) the separation of the profession of the physician from that of the pharmacist, and ii) the systematic taxonomy of stones in Arabic alchemical and gemmological works, which was much more accurate than equivalent Western discourses on lapidaries, the authors of which were apparently not aware of the most important texts such as Theophrastus' *On Stones*. Instead, both Jabir ibn Hayyan and Muhammad ibn Zakariya Al-Razi articulated a phenomenological classification for the stones, in which *lapis* was given a precise place [11].

Yet, the Medieval Latin medical tradition was aware of the use of *lapis*. Simon Januaensis' *Clavis Sanationis* – a late 13th Century medical dictionary with alphabetical entries – mentions two kinds of *lapis*, the first "est laudabilis mundus a marmore albo et a marcasita" and the second, unsuitable for medical uses, "est fragilis minus pulchri coloris veluti terra azurina qui citra mare nascitur" [12]. The distinction between the two types of *lapis* by means of the Latin prefixes c*itra-* and *ultra-* and the presence of two accessory minerals of *lazurite* (likely calcite and pyrite) was acknowledged in the 13th Century. Ground *lapis lazuli* was also known to be useful for the production of: i) blue enamels of Roman glass (2nd Century [13]); ii) blue coloured inks used in Muslim MSS (11th Century [14]); iii) glazes of monochrome Egyptian blue faience (1st century BC-1st Century AD), glazed potteries of Southern Italy and Iranian ceramics (13th century; for a review see [15]).

2.2. The first uses of *lazurite* as a pigment on various supports

The new sophisticated chemical-physical procedures [16] have not been able to determine if the painters/illuminators themselves produced the *ultramarine* powder or if they bought it. Besides, the early tracts *on mercatura* did not pay attention to the trade of *lapis lazuli* or its powder. In any case, the reliable new data available since the late 80s makes it possible to change the traditional approach to the social history of *ultramarine*, which was lead by the 1849 seminal work by Mary P. Merrifield, whose *Original Treatises on the Arts of Painting* was mainly based on 14th and 15th Century literary records.

2.2.1. The first Western use of *lazurite* on walls and other supports

N.	Date	Place	Artefact	Authors
1	1580 to 1550 BC, 17th Dynasty	Egypt	funerary artefact	[17]
2	1580 to 1550 BC, 17th Dynasty	Egypt	statue	[18]
3	13th c. BC. Mycenaean Greece	Gla in Beotia (Gr)	wall	[19]
4	1st c. AD	Roman Colchester (UK)	wall	[20]
5	3th or 4th c. AD	Egypt	canvas	[21]
6	first half of the 8th c. AD	San Saba Church, Rome (It)	wall	[22]
7	last quarter of 8th c. AD	Tower of Torba (It)	wall	[23]

Table 2.2.1. Western European notable occurrences of *lazurite* on walls and other supports

The presence of *lazurite* in the 8th Century wall paintings of Rome, San Saba Church (see record no. 6 in Table 2.2.1) is largely accepted.

According to scholars, record no. 1 may be an unusual pigment that could have resulted from a previous restoration [17], whereas record no. 5 is a sample contamination [21]. In summary, there is some unwillingness to accept the idea that *ultramarine* could have been used before the medieval times. According to Heywood, at that time the pigment was obtained by grinding high-quality *lapis lazuli* [18]. In addition, the use of *lazurite* has been recognised in France, Germany, and Northern Italy [24].

2.2.2. Notable Western European occurrences of *lazurite* on MSS

In this section we cite only the first cases of the use of *lazurite* and the transition from an organic (woad/indigo) or inorganic (*azurite*) blue to the much more costly *lazurite*.

The oldest Western notable cases are the following three 9th Century MSS: the first two belong to the Archivio and Biblioteca Capitolare of Vercelli (Italy) MS CIV [25] and MS CCII (personal communication by Maurizio Aceto, data not yet published), and the third is the Biblioteca Apostolica Vaticana (BAV) MS Vat. Reg. lat. 124, written in Fulda or Mayence [26]. Six other cases have been recorded in the 10th Century. The transition from an organic blue dye to *lazurite* was documented in the 11th Century in France (Fécamp Abbey) [27] and England [28], and one Century later in Italian Tuscan manuscripts, in which *azurite* was substituted for *lazurite* [29]. From the 12th Century onwards, the use of *ultramarine* was no longer restricted to any specific geographic areas and became common all over Western Europe.

2.2.3. The oldest use of *lazurite* in Byzantine artworks

Written data on the pigment palette used in the Byzantine manuscripts is scarce and attestations of the use of *lazurite* between the 6th and the 10th Centuries AD are still limited.

The oldest source (beg. of the 6th Century) is the well-known *Dioscorides Vindobonensis*, a precious and elaborate volume given as a gift to the Western Roman imperial princess Juliana Anicia [30]. The second case is the mid 6th century *Codex Rossanensis* at the Museo Diocesano in Rossano Calabro (Cosenza, Italy) [31].The third case is the late 6th Century Rabbula MS of Syriac origin [32]. This is a concordance case with the authors of San Saba's wall paintings of the Christological cycle in which *lazurite* was used, because the painters were of Syriac origin [22].

A *badly washed ultramarine*, to use Laurie's visual-based interpretation, was used by the illuminators of a 6th Century Byzantine MS Add. 5111, at the British Library, as was the blue colour of the *Lindisfarne* Gospels (a Hiberno-Saxon MS copied at the beginning of the 8th Century) [33]. More recently, Brown and Clark have demonstrated the absence of *ultramarine* in the latter manuscript after a more sophisticated and reliable technique of analysis had been developed [28].

2.2.4. The oldest use of *lazurite* in Arabic artworks

Only a limited number of publications are devoted to the pigments used in early Islamic artworks. The earliest findings of the use of *ultramarine* are from the Umayyad period. A few pages of a Qur'an dated at the end of the 7th Century or the beginning of the 8th Century (Paris, BNF, MS Arabe 330c, ff 11-19). Another few pages of a second Qur'an dated to the 8th Century (Paris, BNF, MS Arabe 324c, ff. 8v, 14v, 18v, 32r, 36v, 39r) [34]. The fresco paintings of the Umayyad rest place at Qusayr Amra, Jordania of the first mid 9th Century (or *ante* 811-812) show the influence of Byzantine and Sasanian art on the iconology and painting procedures [35].

2.2.5. The oldest use of *lazurite* on wall paintings in Asia and central Asia

In Asia and central Asia *ultramarine blue* was mainly used in connection with the spread of the Buddhist cult from India through central Asia. In most of the cases the Buddhist temples were excavated from cliffs. The early use of natural *ultramarine* was identified in the 4th Century murals of the Kizil Grottoes caves 38 and 114, on the Northern route of the Silk road around the northern edge of the Taklimakan desert (Central Asia) [36; 37]. From the 4th until the 8th Centuries, some of the wall paintings of its 236 rock-cut caves were performed using *ultramarine blue*, which was identified by X-ray diffraction [37]. Subsequently, *lazurite* was used in the wall paintings of caves 251 and 259 of the Dunhuang caves (Gansu, North-western

China), about 1.500 km east from Kizil, in the early Wei period (439-534 AD) [38]. Zuixiong dates some caves to the period 304-581 AD [37].
Westward to Kizil, *ultramarine blue* was utilised for wall paintings in Afghanistan, Uzbekistan and Tajikistan (5^{th}-8^{th} Centuries). The analysis of the pigments of the wall paintings of Central Asia (now in the State Hermitage Museum) shows that the use of *lazurite* was common in pre-Islamic times in the murals of the Bāmiyān and Kakrak Buddhist caves (Afghanistan), in the Buddhist Monastery of Ajina-Tepa (Uzbekistan), in Afrasiab's aristocratic block of houses – now the ruins of ancient Samarkand – and in the centres of Shahristan and Panjikent (Tajikistan) [39].

Some concluding notes

As far as the geographical distribution of the use of *lazurite* on MSS in Western Europe is concerned, the literature is far from satisfactory. Nevertheless it seems safe to assume that the transition from a blue dye/pigment to *lazurite* occurred in the 11^{th} Century in France, Germany and England, and a century later in Italy.
A second reflection relates to the Arabic influence: the oldest attestations in Byzantine MSS of the pigment, and the murals in Asia and Central Asia with *lazurite* were painted in a period preceding the Islamic invasions. From a chronological standpoint it seems plausible that the Persian word *lajward* became a Greek loanword without necessarily being translated into Arabic.
At the present state of the literature, there is a time gap of about three centuries between the Byzantine and Western use of *lazurite* on MSS.

2.3. Medieval Western recipes for the making of *ultramarine blue*

In the mid-30s Daniel V. Thompson drew attention on the three earliest medieval MSS on the procedures for achieving *ultramarine*: i) Cambridge, Gonville and Caius College, 214 (James 181); ii) London, British Library, Sloane, 342; and iii) Bologna, University Library, 153 [40].
The first MS – a 13^{th} Century record – transmits Michael Scot's *Tractatus alkimie* with a final section containing the recipe *Azurum transmarinum hoc modo per pastillum afinatur* (f. 32, r. 21; on the chemical reaction between the *pastillum* and the ground minerals see [41]). The difference between the *lombardicum* and *transmarinum azurum,* the composition and the procedure *per pastellum* for achieving the pigment are clearly stated, while the basic pH value of the procedure is not yet present. Both the procedure and the composition of the *pastellum* are recorded in the other two MSS, in which no distinction between two types of azure is made. Sloane's recipe *Si vis facere azurium* (f. 132v, r. 11) is part of a 13^{th} Century small collection of colour making recipes entitled *Massa de coloribus,* which is located among medical texts grouped to form a *compositus* codex. The alchemical Bologna MS may be most likely dated to the turn of the 14^{th} Century: it includes tracts on falconry and alchemy, besides the *Liber claritatis* and its recipe *De azulo faciendo* for producing the *azurum* (f. 11v, r. 17).
The modern terminology (*lapis lazuli* and *ultramarine azure*) had not yet been fully developed in the 13^{th} Century. The recipe *Nobile azolum ultramarinum conficitur sic* (f. 61v; BAV, MS Vat. Lat. 598, 13^{th} Century) contains one of the first attestations of the term *ultramarine*, although not concerning the production of *ultramarine* [42].

Yet the term *ultre-mer* was already present in the *Chanson de Roland* (67, 3156, 3507; 2nd half of the 11th Century).
From Thompson onwards, the art historians struggled with two main questions: when *ultramarine blue* became a common pigment in wall paintings and MSS in Western Europe and how big was the time gap between the Western use of *lazurite* and the 13th-14th Centuries recipes. The literature shares Thompson's view that the blue extracted from *lapis lazuli* "was used in Europe long before any of the recipes for extracting it […] were written" [43]. For Thompson, *ultramarine* was not common before the 14th Century, but recent literature refutes this view and there seems to be no consensus on the extent of the delay between the first actual use of *ultramarine* and the 13th-14th Centuries recipes for producing it.
The ability to produce *ultramarine* and its description in literary records belong to different types of *chaînes opératoires* [44]: the first use was in the context of the practical art of painting and the second in the noblest art and science of medicine and the lesser noble alchemy. However, since Thompson's study, little research has been undertaken on cultural and socio-economic contexts, and linguistic and procedural aspects of the social uses of ground *lapis lazuli*.
The Islamic literature provides this information with respect of Western sources: for instance, two authors specify data for the craft process for obtaining *ultramarine* in a distinctive social context of ateliers expertise devoted exclusively to its making. However, there is uncertainty surrounding the procedure described for getting the pigment (see the 12th Century *Azhar al Afkar fi Djawahir al Ahdjar* by al- Tīfāšī [45] and the 12th -13th Centuries *Bayān al-ṣenāʿāt* by Ḥobayš Teflisi [46]).

3.1. A summary of blue colour terms and substance names from Theophrastus to Isidore of Sevilla

There are at least three determinants that are helpful in distinguishing the linguistic transition from the Greek and Latin colour terms to the medieval terms:
i) Unlike the Mesopotamians and Egyptians, the Greeks and Romans did not have a specific colour term or substance name for what we call today *lapis lazuli* (Sumerian *za.gin*$_3$; Akkadian *uqnû*; Egyptian *ḫsbd*).
ii) Theophrastus' *Περὶ λίθων* (371 –287 BC, *On Stones*) was unknown in the Middle Ages and its influence on the origin of medieval colour term 'azure' appears to be negligible. Moreover, the Greek or Medieval Latin lapidaries cannot be considered a discourse on minerals or rocks in the modern sense because they mainly addressed stone's curative, magical, or mystical and theological properties.
iii) The Latin system of colour terms for 'blue' as a BCT completely fell away in the Romance languages, unlike the case of 'red' as a BCT [47].
The categories of knowledge and the boundaries between disciplines change over time: in fact lapidary's identifying features for stones (the colour, lustre, hardness, occasionally taste, uses and, above all, virtues of stones) are incommensurable with the defining criteria used by modern mineralogy. Therefore we will refrain from addressing the still unresolved questions of the meanings of 'blue' colour terms and substances in Greek and Latin up to Isidore of Seville.
Concerning 'blue' as a BCT, there is a set of Greek and Latin words, some of which worked both as colour terms and substance names, a second stock of classical place-

names and a third set of modern names. The relationships between these three sets of words are yet to be determined:
i) Colour terms: *κύανος* (kyanos), cyanos, *σάπφειρος* (*sappheiros), sappirus*, *caeruleum*, *lomentum*, *vestorianum*, *ḫsbd iryt* (Egyptian = *lapis lazuli from the kiln*), *χρυσοκόλλα* (chrysokólla), *indicum, χυτὸς κύανος* (chytos kyanos = blue smalt).
ii) Place names: cyan from Egypt, Scythia and Cyprus (Theophrastus, *De Lap*., 55; Pliny, *N. H.* 37, 39, 119), Armenian stone (Pliny, *N.H.,* 35, 47; Vitruvius, *De arch*., VII.5.8, VII.9.6).
iii) Modern substance names: *azurite*, malachite, *chrysocolla*, sapphire, *lapis lazuli*, *lazurite*, *Egyptian blue* (a frit containing cuprorivaite), smalt.
From Beckmann's work until today, more than two hundred years passed, but there is still no agreement in the literature about the relationships between the ancient names and mineral substances according to modern mineralogy [48].
Passages in ancient texts that refer to a blue stone with many gold points or golden spots are commonly interpreted by scholars just as *lapis lazuli* (see for example Pliny the Elder, *N.H.* 37, 38,119 or Isidore of Seville's *Etymologiae*, 16, 9). In this way, sapphire was equated with *lapis lazuli*, whilst recognising that the ancient sapphire should not be identified with the modern oxide of aluminium (α-Al_2O_3), whose colour is caused by trace amounts of elements.

3.2. The *λαζουρ-* (*lazour-*) word root in the *Thesaurus Linguae Graecae*

The very large corpus of the TLG includes eleven attestations for the root word *λαζουρ-* (*lazour-*). Two of them are not well dated and three others are placed outside our chronological limits. Moreover, the *Commentarii in Apocalypsin* by Arethas of Caesarea, already known in the literature [49], are not included in the TLG. As a result, there are seven useful attestations, summarised in Table 3.2. Five cases precede the first two 9th Century Western attestations of the Latin lemma *lazur*.
We cannot discuss the seven cases thoroughly due to the restricted number of pages we have in this paper. Nevertheless, we emphasise that Beckmann addressed this lexicological aspect and already noted the attestation of records nos. 4 and 5 [1]. Unfortunately, the present literature does not show further progress with respect to Beckmann's [1] and Ploss'works [49].
The word *lazourin* (*λαζοῦριν*) in Book I of the *Cyranides* (record no. 1; 4th Century [50]) indicates a kind of a sapphire, or a dark blue stone (*Σάπφειρος λίθος, ἢ κυάνεος*) with golden veins (*φλεβία χρυσᾶ*), which was used by painters (*ζωγράφοι*) in order to obtain natural *lazurin* (*λαζοῦριν φυσικόν*). *Cyranides* is a magical lapidary; a similar magical context is also shared by record no. 2 [51].
Record no. 3 is of an astrological character and mentions the colour *lazuron* (*Λαζουρόν*) in the description of the moon [52]. Records nos. 4 and 6 belong to the genre of Christian lapidary. Among these, the mid 12th Century *Prüller Steinbuch*, in which the less known *sapphire* is compared to the better known *lasu*r [53].
The four editions of the *Eparchicon Biblion* (record no. 7) – the first three by Nicole (1893), Boak (1929), Freshfield (1938) – translated the term *λαζούρην* differently and no reference to *lapis lazuli* is made, except in Koder's critical edition [54]. The section quoted from the *Eparchicon Biblion* concerns perfumers or dyers:

perhaps the word *perfumer* means druggist, analogous to the Islamic specialisation of the profession of the pharmacist, as suggested by the fact that the preparer of the drugs was named *aṭṭār*, i.e. perfumer [55].

No.	Text's title	Meaning	Context	TLG's reference	Date
1	*Cyranides*	*Λαζοῦριν* (*lazourin*) indicates the name of a pigment.	Hermetic lapidary with medico-magical aims	Book I, sec. 18, line 10.	4th c.
2	Astrologica *Hygromantia Salomonis*	*λαζουρίου* is the name of a coloured substance.	Prescription of a spell	Vol. 8.2, page 158, line 25.	5th-6 th c.
3	*Palchus*, *Dodecaeteris chaldaica*	*Λαζουρόν*: Selene's colour is like the less known colour *lazuron.*	Description of the colour of the moon (astrological genre)	Vol. 5.1, page 182, line 32.	7th c.
4	Andrew of Caesarea, *Commentarii*	*Λαζούριον* is a substance or the name of a colour like the body of the sky and of sapphire.	*Book of Revelation*: description of the city wall of the Saints, which is adorned with precious stones.	Logos 23, chapter 67, section 21.19c. line 2.	7th c.
5	Leontius Mechanicus, *De praeparatione sphaerae Arateae*	*Λαζουρίωι* is the name of an opaque (azure) pigment or dye.	Description of the astronomical globe: one of the circles is painted in azure.	Sec. 5, line 20.	7th c.
6	Arethas of Caesarea, *Commentarii in Apocalypsin*	*Λαζούριον* is the name of a colour that is comparable to sapphire.	*Book of Revelation*: description of the city wall of the Saints, which is adorned with precious stones.	Migne J.P. (ed.), 1866, *Patr. Grae.,* 106, 773-4.	9th-10th c.
7	*Eparchicon Biblion*	*Λαζούρην* is sold by perfumers.	List of traded goods in an administrative-economic context.	Chapter 10, section 1, line 7.	10th c.

Table 3.2 The attestation of the root word *λαζουρ-* (*lazour-*) in the *Thesaurus Linguae Graecae*

Some concluding notes

This section demonstrates that the root word *λαζουρ-* may refer both to a colour term and a colouring agent. The first attestation in the 4th Century seems to be the intermediate between the notable case of Colchester (1st Century AD), and the Dioscorides MS at the Wien Library (6th Century AD) (see Tables 2.2.1 and 3.2), while the dating of Egyptian canvas fits with the oldest literary record of the TLG (3th or 4th Centuries AD).

If one considers *ultramarine* as a case of ground *lapis*, then it is possible to rationalise why *lazurite* was sporadically (?) used as a pigment a long time before its use in Central Asia and Europe.

The spreading of the use of *lazurite* from Central Asia may justify only a part of this scarce set of notable occurrences. A more general hypothesis could be a multiple and uncorrelated set of inventions of ground *lapis lazuli* as a pigment.

3.3. The first attestations of the Latin lemma *lazur-* and the *Compositiones lucenses* tradition up to the 13th Century

The first Medieval Latin attestations of the word *lazur* come from two 9th Century literary records. The first one – a reference to wall pigments – is a letter by Frothar, bishop of Toul (813 – 847†), already quoted in Du Cange's *Glossarium Ad Scriptores Mediae et Infimae Latinitatis*. The other record is the well-known recipe book *Compositiones lucenses* (MS 490) held by of the *Biblioteca Capitolare* of Lucca, copied between 787 (or 796) and 816. Recent acquisitions on Lucca's contents stress that the latter is severely disordered and fragmentary and consequently the study of *Compositiones lucenses* cannot rely exclusively on this manuscript and may be only fully understood by integrating its texts with the entire tradition (hereafter CLT), which consists of 26 MSS [56].

CLT recounts on twelve manuscripts up to the 13th Century; eight show the use of the term *lazurin* in 17 text-units, 7 of which were already registered by Lucca MS. There are a further 14 MSS from the 14th to the 17th Centuries, but only two of them provide new passages including the term *lazurin*. These two MSS at the National Central Library in Florence, although useless for our purposes, should be mentioned for the sake of completeness: the MS Palatino 951 (late 14th Century, see f. 11r) and the alchemical MS Palatino 981 (late 15th Century, see f. 8r), which include recipes for colour making both inside the CLT and other unknown sources.

MSS list: Lu_Lucca, Biblioteca Capitolare, 490 (8th-9th c.) || K_Klosterneuburg, Stiftsbibliothek, frag. s.n. (9th c.) || S_Sélestat, Bibliothèque Humaniste, 17 (10th c.) || C_Corning, Museum of Glass, Phillipps 3175 (12th c.) || L_London, British Library, Add. 41486 (12th c.) || V_Città del Vaticano, Biblioteca Apostolica, Reg. lat. 2079 (12th c.) || Ob_Oxford, Bodleian Library, Bodley 679 (13th c.) || Od_Oxford, Bodleian Library, Digby 162 (13th c.).	
1	Lu: f.220v, r.7 || S: f. 28v, r.16 || C: f. 41v, r.12 || V: f. 85v, r.29 || L: f. 99r, r.24 || Ob: f. 27r, r.1
2	Lu: f. 224r, r.4 || S: f. 15v, r.4 || C: f. 25v, r. 16 || V: f. 76v, r.3 || Ob: f. 29r, r.43 || Od: f. 20ra, r.17
3	Lu: f. 224v, r.21 || S: f. 46r, r.8 || C: f. 35r, r.12 || V: f. 77r, r.30 || L: f. 94r, r.22 || Ob: f. 28v, r.45
4	Lu: f. 225r, r. 24 || K: f. 1r || S: f. 48r, r. 12 || C: f. 37v, r. 8 || L: f. 96v, r. 23 || Ob: f. 29v, r. 22
5	Lu: f. 225r, r. 28 || K: f. 1r || S: f. 48r, r.9 || C: f. 37v, r. 5 || V: f. 78r, r. 26 || L: f. 96r, r. 20 || Ob: f. 29v, r.10
6	Lu: f. 225r, r. 24 || K: f. 1r || S: f. 48r, r. 12 || C: f. 37v, r. 8 || L: f. 96v, r. 23 || Ob: f. 29v, r. 22
7	Lu: f. 225v, r. 4 || K: f. 1v || S: f. 48v, r. 17 || C: f. 38r, r. 17 || V: f. 78v, r. 12 || L: f. 97r, r. 7 || Ob: f. 29v, r.25
8	V: f. 77r, r.30
9	S: f. 47r, r.5 || C: f. 36r, r.16 || V: f. 77v, r.23 || L: f. 95r, r. 20 || Ob: f. 29r, r. 16
10	S: f. 47r, r. 15 || C: f. 36v, r. 16 || V: f. 77v, r. 30 || L: f. 95v, r.8 || Ob: f. 29r, r.23
11	S: f. 47v, r. 5 || C: f. 36v, r.19 || V: f. 78r, r.4 || L: f. 95v, r. 21 || Ob: f. 29r, r. 30
12	S: f. 47v, r. 17 || C: f. 37r, r.14 || V: f. 78r, r. 14 || L: f. 95v, r.12 || Ob: f.29r, r.41
13	S: f. 47v, r.19 || C: f. 37r, r.15 || V: f. 78r, r.16 || L: f. 96r, r.15 || Ob: f. 29r, r. 42
14	S: f. 48r, r.1 ||K: f. 1r || C: f. 37r, r.17 || V: f. 78r, r.18 || L: f. 96r, r.17 || Ob: f. 29r, r.38
15	S: f. 49r, r. 7 || K: f. 1v || C: f. 38v, r. 5 || V: f. 78v, r.21 || L: f. 97r, r. 14 || Ob: f. 29v, r.31
16	S: f. 50v, r.9 || C: f. 40v, r. 18 || V: f. 79r, r. 34 || L: f. 99r, r. 6 || Ob: f. 30r, r. 19
17	C: f. 63v, r. 20

Table 3.4: Concordances of the term *lazurin* in CLT's MSS

Table 3.4 contains concordances of the term *lazurin*, sufficiently detailed in this respect just to underline how the Latin lemma *lazur* could have different meanings. *Lazurin* is a compound (1) and *azur* is milled (17). *Lazurin* is an ingredient of a mixture of reddish/purplish colour (4,5,6,7,9,11,12,14,15). *Lazurin* is specified using set of additive terms: *lazuri zonta* (3), similar to woad/indigo; *porfyrizonta* or *lazurin diforon qui dicitur bifaces* (9), purplish hue; *lazurin melini zonta* (10), a greenish azure; *lazurin erinon* or *aereum* (11) sky-azure; *Lazurin carnei coloris* (12), an azure of a flesh-colour; *lazuri onichini zonta* (13), onyx-coloured azure.

3.4. The semantic field of blue colour terms and coloured substances in *the Compositiones lucenses* tradition

The terminology provided by CLT for blue coloured substances is even more complex and certainly variegated. Together with *lazurin* analysed above, the same twelve manuscripts use another six words associated with the 'blue' colour: *lulax, venetus, cianus, indicus, hyacintinus, sapphirus*. These terms appear in at least forty-four text-units. A closer look at the data reveals that only a few terms seem so clearly related as to give a specific and recognisable meaning. For instance, the use of *venetus* is triggered by blue coloured substances or products. In stark contrast, all other terms may indicate both a finished product – such as an organic dye, a mineral mixture, or a stone – as well as the corresponding percept colour. A better understanding of 'blue' terms may be achieved through additional work, comparing the set of lexemes of the CLT with that of the coeval literary sources on colours and pigments, but this is beyond the aims of the present work.

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Abstract

In the last fifty years, Slovenia has gained a multitude of new flags that have appeared o to new municipalities, based on local features or attractions, and designed in accordar with modern trends. On the other hand, a part of the municipal flags represents the herita of the past, the historical traditions and well-known local attractions or identities, e These “older” flags are based on vexillology and heraldic principles, but the seman undertones bear important messages for the study of today’s identity.

In a frame of researching a historic roots, Andrej Skrbinek and Vojko Pogacar used a f methods.

First, a color histogram analysis of the Slovenian municipality flags results in a ranking of color preferences, as shown in Picture 1; the results generally correspond with the m preferred color, stated by older research of the famous psychologists Trstenjak and Tušal

For example, we used a municipality flag of Pivka, which is based on the fictional story Martin Krpan, who became a Slovenian archetypical hero, and is still one, even today. T novel written by the Slovenian writer Fran Levstik, was published in the *Slovenian Gaze* in 1858. The legend refers to the tradition of knights and a flourishing trade with salt, w and saltpeter around the 16th and 17th century. The writer describes the sto metaphorically, influenced by the political situation of the time. In addition, he addec kind of national character awareness. Martin Krpan represents a good, proud a immaculate farm boy—very strong and somehow tough, but very clever, and able to avo all tricks of the court nobility. On one occasion, the Emperor asked him to come to Vien to save the imperial court from the metaphoric-mythical Brdavs, a Turkish conqueror, w already killed a whole range of heroes, including the Emperor’s son. Martin manag cleverly to overcome Brdavs, and so he obtained a life license for the salt, wine a saltpeter trade. Martin Krpan represents, even today, a kind of resistance spirit and sufficient degree of cleverness needed to dispense with those stronger and in power.

The topics of color and basic formal elements of the municipal flag of Pivka will researched through criteria of symbolic structure; “local or position” in structur topological or symbolic, virtual space representing the real “subject,” as indivisible, a connected to real space, linked to transcendental topology. The sense of the symbo elements emerges from their position in space. This way the symbolic tends towards ro playing of positions, and towards the imaginary character of a human being. “Criteria distinctive and special of 'photem'” [1], or the smallest “linguistic” units of the “fo language,” symbolizing functions and variables of the “form language” whose subject the structure by itself. The next differentiating criterion will be virtual as modus of t structure as the subject of theory, where time flows from virtual towards actual—towa actualization of the virtual structure covered by its impacts. The figure of Martin Krpan not only an imaginary figure in this case, but also a structural factor in a series

1. INTRODUCTION

Combinations of specific forms and colors represent the most effective method distinguishing between different identities, differentiating identities, and symboliz different entities in the symbolic structure. When forms (objects, items) are similar or ev identical, then only colors remain the most reliable discriminatory factor. Deleuze wrote 1973 [4] that as in classical philosophy and Freudian psychoanalysis, we usua differentiate between the real and imaginary, and that our thought continuously create dialectical discourse between the two concepts. The structural thought recognizes "third field" of philosophic interpretation, as an element of structure: the symbolic. T real and the imaginary, their relations and disturbances are the process' borders of th constitution from the symbolic. The symbolic—as the structural element stands at beginning of a genesis. The structure takes form in the realities and in the images in determinable series. But since the symbolic is deeper, it represents a base for the real a for the imaginary. The catastrophes from the structural symbolic order account for obvic disturbances in the real and in the imaginary. The disturbances in the real and imagina are foreclosured in the symbolic. When not symbolized, they stay captured in the real i hallucinatory form.

The real, after Deleuze, implies an ideal of unification, totality or standardization; it ter towards unity in its "truth."

As soon as we view two in "one," as soon as we double, the imaginary appears subjective, although it operates in the real, as a technical plan, for example. The imagina determines itself through a play of inverse mirrors, reduplications, identifications a projections, by a double's paradigm.

The symbolic for its part is a triple. It is third after the real and after the imaginary, anc also implies a third one; the structure is triadic, simultaneously an unreal and unimaginal third one. The symbolic order is not reducible on the order of the real, not on the order imaginary, and it reaches deeper, as they do. The status of structure is, according Deleuze, identical with the "theory," and the symbolic is understood as the production o theoretic object. In this sense, the symbolic is a source of a living interpretation a creation.

Medieval times in Europe were mainly dominated by general illiteracy and forms of vis identities such as shields, coats of arms, and flags, which were important to unambiguou distinguish the different actors, especially when they emerged as opponents in fighting games, or any expression of belonging, labeling property, possession, etc. [3] In the 1 century, when designing coats of arms and flags, a series of disciplines from herald vexillology, sfragistics, insigniology, iconology emerged, which were among philosophi sciences applied at that time. However, today they are complementary sciences of history.

From the criteria of local, or the position of the symbolic elements in the structure, fro which the meaning arises, as Gilles Deleuze states it in 1973 [4], we concentrate

their historical traditions and well-known local attractions, etc. These “older” flags a
based on vexillology and heraldic principles, but the semantic undertones bear import
messages for the study of today’s Slovenian identity.

In 2005, we researched of the colors on 193 Slovenian municipality flags, which repres
color preferences of the population in a given environment. It was published. [6]
Technically based on research of structural and histogram analysis of colors
municipality flags. We presumed that the part of the historic flags that were leftovers of
heritage were already people’s identity out of habit. On the other hand, we have
multitude of flags of newly created municipalities, which are also selected consensually
accordance with the criteria of the wider local community and, in principle, reflect
general color identity. Perhaps the colors of the flags even more accurately repres
personal color preferences because they are not tied to a pragmatic use, but linked with
symbolic and presentational level. Our results were also in accordance with the previo
research of Trstenjak and Tušak; the average Slovenian’s most preferred color is blue,
an additional important conclusion comes out of this research: green appeared as
second most preferred color and it takes almost a half of positive part of diagram (Fig
1). That is a clearly expressed tendency, which can be noticed as wide-spread in toda
Slovenia. These slight trends were noticed in some parts of Tušak’s research by pupils
technical schools, and partly in vocational and elementary schools (Figure 3).

The new color, photem as a smallest linguistic unit of the form language—green—appe
as a new variable in the symbolic structure of recent Slovenian municipial symbolism. T
status of photem, from a general perspective, is not identical with color *per se*, and is no
fiction or an associated image. As a part of the symbolic structure, photem is real but
actual, ideal but not abstract. Photem “green” in the structure of symbolism is virtual, w
its own reality, as a part of an ideal virtual color pool, where the actualization runs
exclusive ways, implicating partial combinations and unconscious selections. [1][4]

A color histogram analysis of the Slovenian municipality flags results in a ranking list
color preferences, as shown in Picture 1, where results generally correspond with the m
preferred color, stated by older research of the famous psychologists Trstenjak (Picture
and Tušak (Picture 3). In this regard, we must point out important differences with
research of Trstenjak and Tušak; they present in their research positive as well as negat
and indifferent color preferences, but our research focused only on the positive part.

Figure 1: The average of used colors on Slovenian municipality flags shows the same result for first place as the previous research of Trstenjak and Tušak, but green was rank in second place, which is no surprise since this is also observed in Slovenian daily life

Trstenjak researched a sample of 1,000 younger Slovenian students from second schools, aged 15 to 22 years old, 500 male, 500 female, 500 citizens and 500 from a ru setting. The research was conducted with an adequate questionnaire, based on colors clothing and fashion. To make the research frame more real and understandable, he pos questions such as: 1. Which color is generally the favorite at all; 2. Which color is the m preferred in clothes; 3. Which color is the most unpleasant at all; 4. Are the clothes colors that follow fashion or irrespective of fashion, of their own choice; 5. Do they pre a single or multi-colored dress; 6. Do they prefer to dress abstract (geometric) or speci image-like, where they represent something; 7. Do they like color changes, regardless whether the new color is "his/hers" or just fashionable.

This last question is particularly important because it is one of the main characteristics each mode, precisely because rotational dictates of someone else always affect individ taste.

In general, the research examined the popularity and unpopularity of colors. In making t determination, an important difference arises whether it is a personal preference of color for its applied use. For example, someone who likes red will not buy a red coat, something more socially acceptable. In clothing, therefore, we get completely differ results. Trstenjak drew attention to this duality—that personal color preferences differ fr what is socially consensual. These colors are then located in the field among indiffer colors. Under such an interpretation, we can better understand the response to colors bas on the personal emotional level with a difference between social consensus and ratio selected colors. [8]

Trstenjak's research was done around 1975 and presented in his book *Psychology colours*, edited in 1979. As the research is based on his questionnaire, we may suppose t each participant had a slightly individual interpretation of exact color tones, which mea that colors were understood more generally. Confirmation of this thesis can be found in presentation of the results when Trstenjak was still alive. The table in Figure 2 was f presented in his book (1975) close to Cyan - that time called Process blue, meanwhile the second edition Cyan turn closer to Blue out of RGB system.

structure actualizes itself through differentiation in space and time, without differentiat types and parts by itself, which are actualized by space and time; this means that t structure produces the types and parts by itself, as differential types and parts. Each type development runs from virtual towards actual, from the structure towards its actualizati The colors epitomize differential elements and relations, as they simultaneously find th approach and function in the perimeter of the reckogning societal systems or their pa They are essentialy differentiated through the structure, which actualizes itself in them shows itself in them, and which produces them, by actualizing itself. Actually, each them viewed in its actuality, entails the function of another, reflecting it, so that one is danger of finding nothing from this original differentiation produced by transition fr virtual to actual. Deleuze notes that the border runs exactly here, between imaginary a symbolic. Imaginary tends towards reflexion of the total effects of the compl mechanism and refers a concept to each group, whereas the symbolic structure protects t differentiation of effects and terms. Furthermore, Deleuze states that the structures a unconscious, since they are necessarily masked by their products or effects. One can o read, find, and recover the structure from its effects. The elements and relations actualizi it, types and parts realizing it, are simultaneously disturbances and expressions—conce of structural casuality. Structure has an idiosyncratic property by differentiating the effe which simultaneously assimilate and integrate it. The unconscious of structure is differential unconscious, which does not originate from wishes or representation, it "always empty," exists only within structural laws, which it imposes on representatio and wishes. The structure is represented as "field of problems," which a society faces a solves by its means, corresponding the differentializing lines, by which the struct actualizes itself. "Including absurdities, contagiousnesses and prociousnesses, which th 'solutions' based on structure entail." Structural unconscious is, for Deleuze, simultaneu differential, problematizing, questioning, and serial. [4]

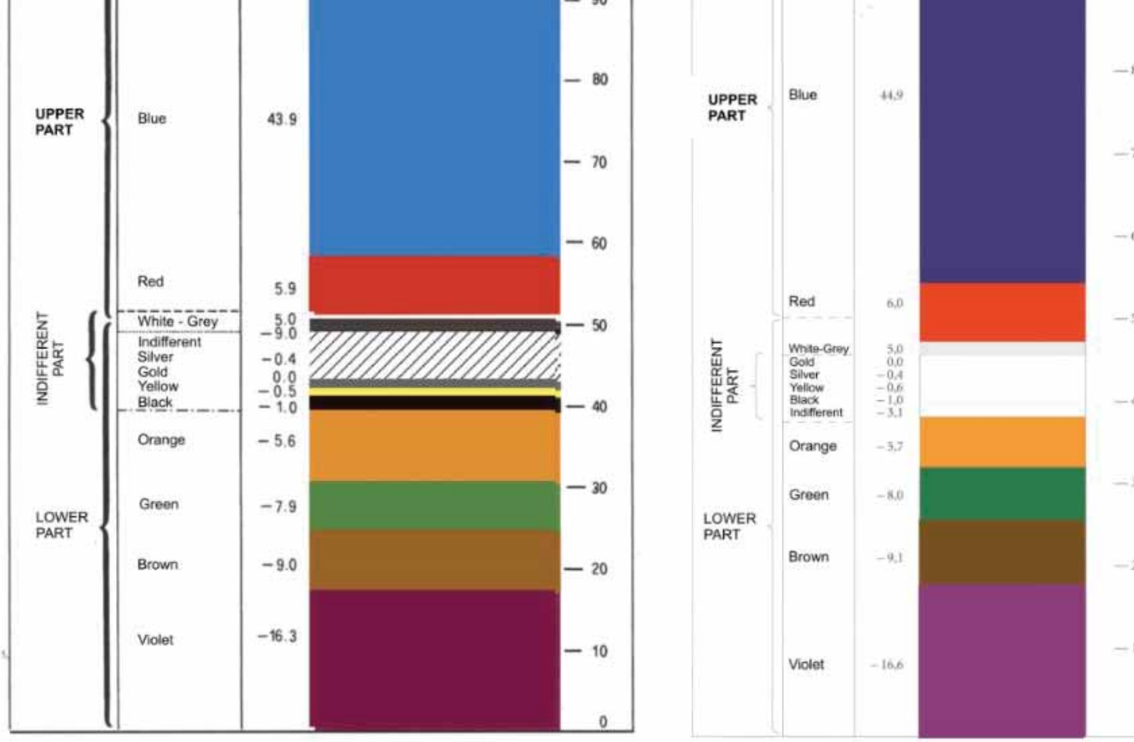
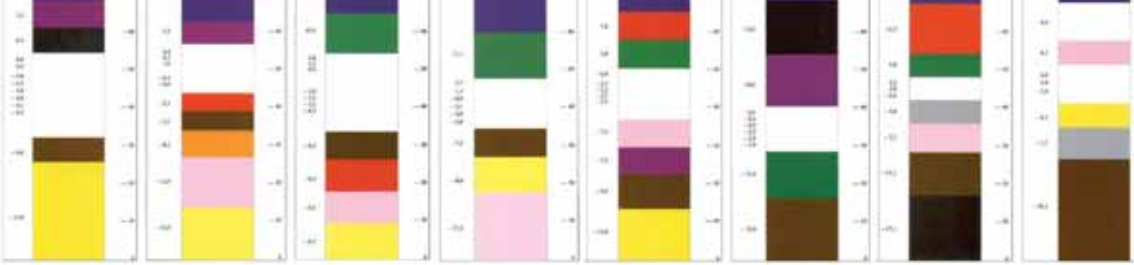


Figure 2: Color preferences of the Slovenian student population by A. Trstenjak (left tab was done in 1975, first published in 1979, and then (right table) in 2001 by M. Tušak. Th differences in printed colors are evident. It is obvious that the colors were meant more in symbolic sense than in a colorimetric sense. [8][9][10]

Psychologist Maks Tušak, who worked for a while with Anton Trstenjak, also continu his research in the frame of improved Trstenjak's methodology. Two decades later, 1995, he carried out a similar survey on a sample of four different types of population secondary school and one elementary school with more than 4000 participants. He a used a similar or even the same questionnaire method, and the results presented in Figur also showed general similarities to Trstenjak's research. Tušak's results were published 2001 and presented in eight tables: the 1st refers to male students and the 2nd to fem students of high school; the 3rd to male students, 4th to male students of a technical scho 5th to male students, and 6th to female students of vocational schools; and 7th and 8th males and females of elementary school.



1 2 3 4 5 6 7 8

Figure 3: Color preferences of Slovenian elementary and secondary school students Maks Tušak performed in 1995 and published in 2001.

In all eight tables in Figure 3, blue is the most prefered, except for the last one, where blue color is in second place, but the general amount of blue and violet together figure a common positive opposition, unlike brown.

The symbolic elements, characterized before, organize themselves in their different relations in series. As such, they refer to another series constituted from other symbo elements, not reproducing or reflecting them. They organize themselves to a second seri capable of autonomuous development, or they relate, as stated by Deleuze, [4] first ser to another one, as photemes and morphemes, as elements of the form's language. Ea structure functions only as multi-serial. The unconscious is intersubjective; therefo organizing the constitutive series of structure implies a real staging. Both series do reflect each other, but are metaphors and metonyms as structural factors, not as imagination's figures.

2. PIVKA MUNICIPIALITY FLAG ANALYSIS

The example of the municipality flag from the small Slovenian city Pivka is based on fictional story of Martin Krpan, who became, and is even now, a Slovenian archetypi hero. The novel was written by the Slovenian writer Fran Levstik, and published in *Slovenian Gazette* in 1858. The legend refers to the tradition of knights and a flourish trade with salt, wine and saltpeter around the 16th and 17th century. The writer descri the story metaphorically, influenced by the political situation of the time. In addition, added a kind of national character awareness. Martin Krpan represents a good, proud a immaculate farm boy—very strong and somehow tough, but very clever to avoid all tri of the court nobility. On one occasion, the Emperor asks him to come to Vienna to save imperial court from the metaphoric-mythical Brdavs, a Turkish conqueror, who alrea killed a whole range of heroes, including the Emperor's son. Martin manages cleverly overcome Brdavs, and so he obtained a life license for the salt, wine and saltpeter tra Even today, Martin Krpan represents a kind of resistance spirit and a sufficient degree cleverness needed to dispense with those who are stronger and in power.

Picture 2: The flag of Pivka incorporates an old Slovenian archetype hero, Martin Krpan, who saved Vienna Court from Brdavs, a one of the Turk invaders in the 17th century.

Dumézil writes in his tripartite ideology of Indo-Europeans, [11] that the three-functio thought, reflected in three "pure" societal classes of priests, warriors and commoners, a developed to symbolism. The three societal groups were mutually bound with sim material objects that evoked the groups and their principles, and led especially to two se to a collection of objects-talismans and to a color palette. Talismans by different Ind European people explained their origin through a mythology of golden items fallen fr the skies, illustrating the societal strata—i.e. a cup for a priest, an ax for a warrior, an plow for a farmer—clearly classifying the values of the three functions. These items w not only mythic, belonging to the symbolic, but were also real, made objects, kept by king, solemnly carried each year over a kingdom. In this sense the ax in the hand and at shoulder of the mythical hero Martin Krpan, depicted on the Pivka municipal flag, clea denotes a warrior, and the bat, in other hand—as an unconventional weapon, construc by unintentional method of design—a robber (*rokovnjač*).

The flag of Pivka consists of white, yellow, blue, black, red and brown color. In connection with Indo-European stratification of the society, Dumézil points out importance and age of symbolic colors for the Indo-Iranian world by the fact that its th functional societal groups denoted with the Sanskrit word *varṇa* and the Avestan wo *pištra* (cf. Greek *ποικίλος*—"colored," Russian *писать* – "write, paint," Slovenian *pis pisan* – "write, colored") which with different shades denote color. In India the *brahma kṣatriya*, *vaiśya* and *śūdra* are denoted by white, red, yellow and black color. This is, af Dumézil, certainly the change of the older system, which is created with establishment o lower and heterogeneous caste, *śūdra*. He finds the traces of this system in rites and Ṛgveda, which says about Agni, the three-functional god, "Black, white, red is his wa X, 20, 9; where the system is composed by only three colors, where black (or dark blu denotes *vaiśya*, cattlemen-farmers. In the Zervanistic-Mazdan tradition in Iran, accord to Dumézil, this system is still kept in its cosmogony, which describes the uniform priests as white, the uniform of warriors as red or colored, and the uniform of cattleme farmers as dark blue. Furthermore, Dumézil notes that other Indo-Europeans had used same symbolism, explaining the Hittite ritual *euocatio* in which they beg the gods o

Mars, Venus/Flora and their obvious functional values of dominion, war, fertility, and w
three initial tribes, which are also ethnic Latins, Etruscans, Sabines, and functional, start
from holy and ruling persons, from professional warriors, and from wealthy shepherds
parallel to the functional tribes by Egyptians and Athenians. The color triad is reflected
old and new religious, folkloric, and literary examples in the area of Indo-Europe
expansion, at its borders, and in regions exposed to the impact of Indo-Europeans.

"Convergent" point of divergent symbolic series is the empty field, as stated by Deleu
[4] a paradox object. This object is extremely symbolic; it represents its own metaphor a
its own metonymy. Symbolic elements and differential relations constitute the series,
the empty field has another nature. Elements' differences and differential's relatio
changes are always determined in relation to it. Both structure series are always diverg
on the grounds of differential law. But this special object is a convergent point of diverg
series, imminent to both series. Deleuze calls it *object* = *x*, enigmatic object and mobile
this object a symbolic "Slovenian identity" in our case? The *object* = *x* is in relation
itself always shifted. It has a property never to be there where one searches for it, a
therefore, one can also find it there, where it does not exist. It is not real, since it has
place; it is not an image, since it detracts itself from its own similarity; it is not a conce
since it detracts itself from its own identity. The whole structure is moved by this prima
third, which detracts from its own origin. Object = x delivers the differences all over
structure, initiates the differential relations with its displacements, and constitutes
difference's derivative *per se*, as a floating, symbolic zero value, circulating in structure
traverses one series as *significant* and another as *signifié*. Its excess of meaning suppl
significant and *signifié* with meaning. The empty field is a word and an obj
simultaneously, which leads the functioning of structures, characterized through the fo
of their symbolic elements, their differential's relation's diversity, and their features' typ
The structures are characterized through the type of empty field. The order of lin
causality from one structure to another can be produced only when one ascribes a kind
identity to the empty field, which essentially resists it. The empty field is determinable,
not fixable to one place, and not identifiable as a category. It has an identity but only
elude from it, and a place only to shift in relation to every place.

The identity shifts through time, from black to blue, from blue to green, from white
yellow in Indo-European identification of three basic societal classes. The fourth one
absent.

3. RESULTS AND DISCUSSION

A final overview of all studies, we found a similar preference for the color blue, with
exception, concerning important changes that appeared in second place in our study w
green. Green means the other half stated at the positive side of the color identity and
importance is increasing with the growth of Slovenian self-esteem. To interpret
pragmatic side of this thesis, we used our PCM (Periodic Color Model), [12] where we

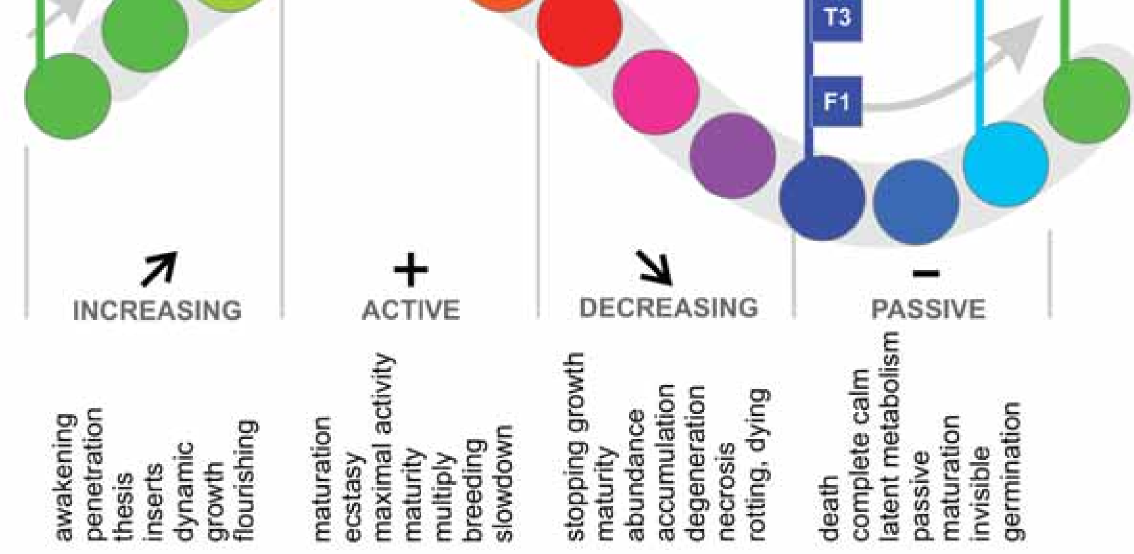


Figure 4: The interpretation in the Periodic Color Model shows general tendencies of research of Trstenjak (T1), (T2) and of Tušak (T3) and of flags (F1). The flag color (F2) the second place shows in which direction general color preferences probably go Slovenia today.

3.1 From subject to praxis

The empty field of "Slovenian identity" is a positive existence of "problematic," object problem's existence and existence of a question. The empty field is followed by extremely symbolic instance, which follows its displacements. Both the instance and place permanently and mutually fail to meet each other, and they accompany each other this way. The *subject* is the instance that follows the empty field. In this way, since empty field is moving, the subject always stays migrant, a nomad. Deleuze characterizes two "big accidents in the structure": (1) a nomadic subject does not foll the empty field any more, which emphasizes its way; its emptiness becomes real. (2) emptiness is fulfilled, occupied by accompanying subject. Its mobility is lost in freezi opulence.

4. CONCLUSIONS

Identified trends in our research have already been noticed in today's manifestations sports as well as in many other fields, mostly related to Slovenian state identity (Figure but the state flag, which reflects a heritage conception of previous times, was not incluc in this research.

For political praxis' interpretation as a permanent transfer point by the criterion "fr

Figure 5: The pictures tell more than a thousand words: color identification of Slove dress in the Olympic games in Sochi 2014 already predict our results in this research.

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The Implicit Association in English of the Semantic Categories BROWN and GREY with PLEASANT

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1. Introduction

Is BROWN or GREY associated more easily with PLEASANT for speakers of English? Both colors are low in saturation, both color terms are associated with feelings of boredom and depression, and at the same time both color terms collocate with words in positive connotations. This paper presents the results of an Implicit Association Test (IAT) developed to ascertain which of the two color category linguistic stimuli is implicitly associated more rapidly with the PLEASANT linguistic stimuli. My hypothesis is that the warmer color of the two, BROWN, will be more easily associated with PLEASANT, even though either color term may be. The results do show an implicit preference for BROWN compared to GREY confirming this initial hypothesis. The *D* measure score, used to quantify the degree of associative strength, revealed a moderate preference for the categories of BROWN and PLEASANT.

The following sections illustrate the IAT test paradigm, the associations made with BROWN and GREY, the experiment including the methodology, an explanation of the experiment stimuli, and a pre-test used to identify them, the results, a discussion of possible guiding conceptual grounds for the automatic attitude, and conclusive remarks.

2. The implicit association task

The IAT is an experimental paradigm developed by Greenwald, McGhee, and Schwartz [1] to study the strength of concept associations in memory, and to explore the unconscious default construals of thinking and feeling. It was originally developed for use in the social sciences.

Greenwald et al. define the IAT in the following way:

> Implicit attitudes are manifest as actions or judgements that are under the control of automatically activated evaluation, without the performer's awareness of that causation. IAT procedure seeks to measure implicit attitudes by measuring their underlying automatic evaluation. The IAT is therefore similar in the intent to cognitive priming procedures for measuring automatic affect or attitude [1] [2].

The individual's performance result is the measure of the differential association of two concepts with an attribute. Greenwald et al. [1] state that their experiments have confirmed the usefulness of the IAT for assessing differences in evaluative associations between pairs of *semantic* or social categories [1]. In the past the IAT has been used to understand evaluative associations that involve social categories and prejudice, discrimination, stereotypes, bias and the relation of self in society [1],

[3], [4], [5], [6]. The Harvard website [7], gives a full explanation of IAT tests and allows one to experience the test and to participate in various studies.

The IAT paradigm establishes a double discrimination task that maps four categories onto two responses. There are three parameters of evaluation: the IAT effect, the D measure and Cohen's d. The difference in reaction time to the categorization grouping of compatible and incompatible associations gives the IAT effect. As Greenwald et al. explain, the IAT effect index is proposed as a measure of relative implicit attitudes toward the categories under investigation. The second parameter is the *D* measure that was developed by Greenwald, Nosek, and Banaji [4]. This measure is a variation of Cohen's d (d = [m1- m2]/SD) effect size measure, which is automatically calculated by the Implicit software. It represents a statistically significant effect of the strength of the relationship between two variables in a statistical population. On the other hand, *D* is more complex and has been developed to deal with effects on latency such as age, individual variability, and error. The measure is explained in the results section. Greenwald and colleagues discuss numerous analyses to compare d and *D* transformations as IAT effect measures, and maintain that the *D* transformations were consistently superior [4]. The present study thus employs the IAT effect and the *D* measure score in relation to BROWN and GREY.

Furthermore, this study represents one of several IAT experiments I have conducted utilizing a novel semantic application of the paradigm that is adopted to understand the linguistic entrenchment of the categories taken into consideration. Sandford [8] presents results regarding the four basic semantic categories RED, GREEN, YELLOW, and BLUE, which implicate the hue dimension. This IAT study tests a differentiation of the two basic color categories BROWN and GREY, which reflect more specifically the saturation dimension.

As mentioned above, the IAT paradigm establishes a double discrimination task that maps four linguistic categories onto two responses. The categories are divided into two target categories, in this case BROWN and GREY, and two attribute categories, in this case PLEASANT and UNPLEASANT. The target categories are usually represented by nouns and the attribute categories by adjectives. This facilitates the association between the attribute and the target. The IAT verifies the speed or the automaticity of categorizing the stimuli with a same response key: e.g. BROWN and PLEASANT vs. GREY and UNPLEASANT, or the opposite. The more compatible the categories are, the easier it is to respond to the task when the specific category items are associated to the same key. In this IAT each conceptual category includes the same number of items with positive and negative connotations, prototypical, metonymic and metaphoric realization.

3. Brown and Grey

Brown and *grey* have certain aspects in common, they refer to lack of energy or purity, and density. They are thus often used to refer to sadness, depression, gloominess, and indistinctness. According to the etymological dictionary [9] *brown* was used to mean dark, dusky and gloomy, and took on the meaning of dark color in the hue sense only in the 13th century. The old English word also had the sense of “brightness” and “shiny”. It is now used mostly regarding skin, fur, hair, or feathers of that color, to describe natural things like wood and earth, or filth and excrement. The two idiomatic expressions using *brown* —to brown nose or to brown off— have a negative connotation. *Brown*, however, is conventionally employed to refer to foods, like bread, coffee, and chocolate. It is used in cooking “until brown”, and as a verb “brown the bird”. *Grey* is typically used to mean dreary, gloomy, having an indistinct quality, neutral or dull, especially in character or opinion. Etymologically *grey* stems from Old English *grǣġ*, from Proto-Germanic **grēwaz*, from Proto-Indo-European **ǵʰer* meaning “to shine, to glow”. Moreover, *grey* is also used with positive associations, such as pearl grey, silver grey, and shiny grey. It is used when speaking of people of middle age or above —grey power, also as a verb, e.g. “just beginning to grey”, or in the computer expression “to grey out” when something is highlighted to indicate that it is inactive at a given time. It may mean ancient; venerable. *Grey* too is used to describe the color of hair, fur, and feathers, or natural things like stone, metals, the sky, and the water. So it would seem that both colors may be considered positive and both stem from a reference to the lightness/brightness dimension of the color frame. The semantics of these color terms have moved from the lightness dimension into the hue dimension, and describe a color of low saturation. The principle difference being that *brown* is a “warm” color and *grey* is a “cool” color.

3.1. Methodology

Materials: An IAT script was developed with Inquisit 4 software [10]. The participants viewed the screen from approximately 50 cm.

Design: Each linguistic category was made up of eight items that were carefully selected through a pre-test. The objective was to identify the most saliently related lexemes in each stimuli category.

Pre-test: To determine the eight stimuli for the two colors categories necessary for the IAT script a pre-test was essential to confirm entrenchment of the associations for speakers of English. The pre-test asked informants to categorize 20 items into the two categories, BROWN and GREY. The pre-test was made to verify the 8 best items of 10 per color. They comprised BROWN: *bear, coffee, bag, toast, chocolate, bread, wood, tanned, earth, nose*; GREY: *elephant, slate, pearl, stone, shade, silver, sky, smoke, ash, matter*. A total of 34 informants responded to the questionnaire. Six different versions of the pre-test were prepared each one presented the items in a different order, to avoid priming responses. The informants were told that there were no “wrong” answers, and that their first response was the right one.

The results are listed in Table 1. Only seven of the items received 100% agreement, five 97%, one 94%, three 91%, one 88%, one 85%, and two 82%. This means that the stimuli selected for BROWN ranged in agreement from 100% to 97%, and for GREY ranged in agreement from 100% to 91%. This result marks the high degree of linguistic entrenchment these items have for the participants, and allowed for the discernment of the IAT items, which necessarily must be clearly attributable to their category. By “entrenchment” I mean the strength of conventional constraints to aspects of word meaning that have attained some sort of default status [11]. Moreover, Langacker [12] differentiates between “entrenchment”, or unit status, pertaining to individual speakers' usage, and "conventionality" pertaining to community of speakers. The basic idea is that for the IAT to function properly it is essential that the stimulus items not permit alternate interpretations of category contrasts.

ITEM	BROWN % agreement	GREY % agreement
bear	100	0
chocolate	100	0
coffee	100	0
tanned	100	0
toast	100	0
elephant	0	100
slate	0	100
bag	97	3
bread	97	33
wood	97	3
sky	3	97
silver	3	97
nose	94	6
pearl	9	91
shade	9	91
smoke	9	91
stone	12	88
ash	15	85
earth	82	18
matter	15	82

Tab. 1 – Pre-test results, percentage of agreement for 34 informants.

Linguistic Semantic Experimental IAT Stimuli: Following these results the target items selected for the IAT stimuli are BROWN: *bear, coffee, bag, toast, chocolate,* *bread, wood, tanned*; GREY: *elephant, slate, pearl, stone, shade, silver, sky, smoke*. I chose to utilize the same attribute items that are used in the original FLOWER - INSECT IAT [1] script for the categories PLEASANT and UNPLEASANT for association with the basic color categories. They are PLEASANT: *joyful, beautiful, glorious, superb, wonderful, marvelous, pleasure, lovely*; and UNPLEASANT: *horrible, agony, painful, nasty, awful, humiliate, terrible, tragic.*

Instructions: Each Trial block started with instructions that described the category discrimination(s) for the block and the assignments of response keys (left or right) to the categories. Reminder labels in the form of the category names were appropriately placed in the left or right corner of a black screen during each block, and the targets and stimuli were indicated in white print, while the attributes and stimuli were indicated in green print. The test was administered, as required, in seven blocks, for a total of 180 items per test.

The participants were told through on-screen text to use the "E" and "I" keys to categorize items left and right, to go as fast as possible, and if they made an error (and a red X appeared on the screen), they should correct it by hitting the other key, before proceeding. They were then reminded to note when the categories had switched positions. The concept that was previously on the left was practiced on the right, and vice versa. Moreover, they were told when the four categories appeared together in a new configuration, and were reminded that each item belonged to only one group.

The blocks include practice and 'critical' responses. The columns indicated here refer to Figure 1. They are divided into the following blocks:

B1) target compatible practice—20 items, column 1;

B2) attribute practice—20 items, column 2;

B3) compatible test I—20 items, column 3;

B4) double compatible test II—40 items, column 3;

B5) target incompatible practice—20 items, column 4;

B6) incompatible test I—20 items, column 5;

B7) double incompatible test II—40 items, column 5.

Completion took approximately 5-10 minutes.

The critical blocks were considered *compatible*, when the hypothesized default construal "target attribute" shared a response key, BROWN and PLEASANT, and *incompatible*, when the opposite, GREY and PLEASANT, shared a response key, see Figure 1.

The data for each trial block included response latencies in milliseconds and error rates. The items and block category screen sides were randomized, leaving the practice blocks before the critical blocks.

The *D* Score: The *D* scoring algorithm is recommended as a general replacement of the previous conventional procedure "Cohen's d", thus I present only the *D* score and the IAT affect.

Sequence	1	2	3	4	5
Task	Initial target-concept discrimination	Associated attribute discrimination	Initial combined task (compatible)	Reversed target-concept discrimination	Reversed combined task (incompatible)
Task instruction	● BROWN GREY ●	● PLEASANT UNPLEASANT ●	● BROWN ● PLEASANT GREY ● UNPLEASANT ●	BROWN ● ● GREY	BROWN ● ● PLEASANT ● GREY UNPLEASANT ●
Example Stimuli	○ bear elephant ○ ○ coffee slate ○ ○ bag pearl ○ ○ toast stone ○	○ marvelous tragic ○ horrible ○ ○ superb ○ beautiful agony ○ ○ glorious awful ○	○ bear tragic ○ ○ superb elephant ○ ○ bag agony ○ ○ glorious stone ○	toast ○ chocolate ○ ○ elephant bag ○ ○ stone ○ silver coffee ○ ○ shade	bear ○ toast ○ ○ marvelous ○ silver bread ○ ○ pearl horrible ○ ○ beautiful

Fig. 1 - Schematic illustration of the IAT. The IAT procedure foresees five discrimination tasks, one in each column. The target and the attribute concepts are presented in the first two tasks. Categories for each of these discriminations are assigned to a left or a right response key, indicated by the black circles before or after the categories. These are combined in the third task, the target concept is reversed in the fourth task, and then the combined categories are also reversed in association in the fifth task. The schema then illustrates the stimuli for the specific tasks for each of the conditions, with correct responses indicated as open circles (adapted from [1]).

The following is a summary of *D* measure for IAT scoring procedures recommended by Greenwald et al. [4]. The first steps are for data reduction: 1. Delete trials with latencies greater than 10,000 ms. 2. Delete participant results for whom more than 10% of trials have latency less than 300 ms. Then there are 7 further steps to calculate *D*: 3. Calculate the means of all the 'correct' trials for each Block: B3, B4, B6, and B7. 4. Calculate the standard deviation (SD) of all the trials in (B3 + B6) and for all trials in (B4 + B7), before error correction. 5. Replace all the 'error' latencies with mean compatible (B3 + 600 ms) and mean compatible (B4 + 600 ms), and mean incompatible (B6 + 600 ms) and mean incompatible (B7 + 600 ms). 6. Calculate the mean latency for responses for each critical block with corrections: B3, B4, B6, and B7. 7. Compute the two mean differences (Mean B6 – Mean B3) and (Mean B7 – Mean B4). 8. Divide each difference score by its associated standard deviation (Step 4). 9. *D* = the equal-weight average of the two resulting ratios (*D* = M/SD). (Adapted from [4], [5]).

Classification of the associative strength of the IAT *D* scores obtained in our tests are: 0 to 0.15 'little to no', > 0.15 'slight', > 0.35 'moderate', and > 0.65 'strong'; as indicated in the expression values magnitude in the Inquisit software script. Test results were reported as showing "little or no", "slight", "medium", or "strong" strength of one of the association contrasts measured by the test. The slight, moderate, and strong labels correspond to results meeting the conventional criteria for small, medium, and large effect sizes of Cohen' s (1977) d measure [1], [4].

The IAT was administered to 31 volunteers, who were native speakers of English, mean age 27.

3.2. Results

The analysis of the RAW IAT scores, Figure 2, shows an IAT effect of 163 ms, which is the difference between the compatible and incompatible mean response latencies. The average RAW latencies of all the trials was 898 ms for the compatible tasks (BROWN with PLEASANT) vs. 1061 ms for the incompatible association tasks (GREY with PLEASANT); see Fig. 1 columns 3 and 5 respectively. This result shows a more rapid associative speed for BROWN with PLEASANT.

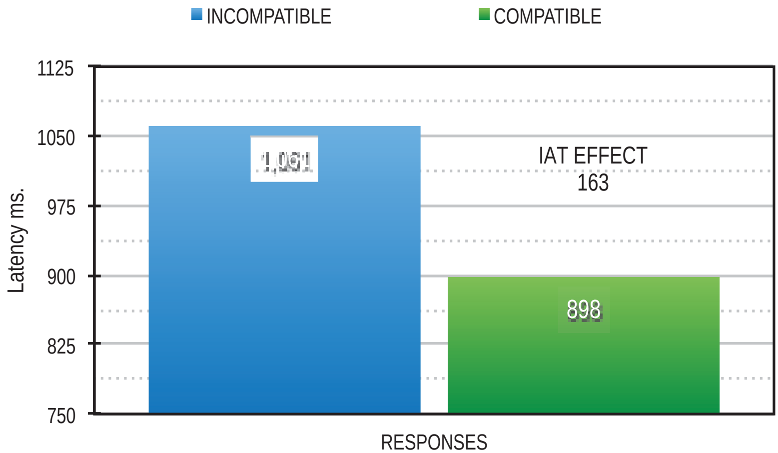

Fig. 2 - Mean latencies of RAW data, IAT effect for compatible (BROWN and PLEASANT) vs. incompatible (GREY and PLEASANT) association.

In the analysis of the individual IAT scores, on the average 81% of the participants show a *moderate* preference for BROWN. Of this 81%, 40% showed a *moderate* preference, 24% showed a *strong* preference, 20% a *slight* preference, and 16% *little to no* preference. Instead, the remaining 19% of the individuals revealed a associative preference for GREY, within which 66% showed a degree of *little to no* preference, 17% showed a *strong* preference, and another 17% showed a *slight* preference, none of the individuals showed *moderate* preference.

There was a *moderate* automatic preference for the concept BROWN, not a *strong* preference. Nonetheless, it is pertinent to highlight that the preferences for GREY resulted in a higher percentage of associative value in the lower range of assessment (little to no preference). Lastly, a robust majority of the participants did show a implicit attitude that favors BROWN over GREY, though they did not demonstrate a unanimous implicit attitude toward BROWN or GREY. On the other hand, GREY preference emerged to a slight degree. Therefore, though the original hypothesis that BROWN be associated more easily with PLEASANT became apparent as expected, the distance between the two concepts is not as neatly delineated, but shows a gradual cline in degree of individual associative values.

The *D* score in Fig. 3 illustrates this same result, which is *D* = +0.38 or a moderate associative strength for BROWN and PLEASANT.

D Score	
BROWN and PLEASANT COMPATIBLE	+0.38

Fig. 3. D score moderate associative strength for BROWN and PLEASANT.

4. Discussion

In observing the task responses, it is relevant to mention that GREY and UNPLEASANT category items registered a higher rate of error, see Table 2 for those items that had 10% error or more. They were *elephant*, *sky*, *pearl*, and *smoke* for GREY, *nasty* and *agony* for UNPLEASANT. Only one item in the BROWN category had 10% error, which was *chocolate*. This difference in error most certainly contributed to the differentiation in the measure of associative strength. At the same time it is obvious that there should be no difficulty in categorizing *elephant* or *pearl* as GREY nor *nasty* and *agony* as UNPLEASANT, or *chocolate* as BROWN. Table 2 illustrates the item, category, percentage of error and the number of errors in relation to the number of occurrences. The number of occurrences varies since the items are randomized across the tasks for each participant.

Another pertinent observation is that the number of errors was greatly superior for the incompatible tasks. This is the decisive element, not only does the incompatible category coupling take longer to process, but the incompatible tasks drive the participant to make errors of the unequivocal category items.

ITEM	CATEGORY	% ERRORS	N. OF OCCURRENCES
elephant	GREY	16%	18/113
sky	GREY	16%	18/114
nasty	UNPLEASANT	13%	14/109
pearl	GREY	11%	13/117
agony	UNPLEASANT	10%	11/115
smoke	GREY	10%	11/105
chocolate	BROWN	10%	10/103

Tab.2 – Stimuli with over 10% of error with number over total occurrences.

Moreover, there was lower consensus in the pre-test categorization of the GREY items. This could be relevant in showing a lesser degree of default status in the object associations. Grey by definition represents a neutral quality and means lacking in distinctness. I argue that the meaning of the word primes a reaction that it defines.

This brings me to argue that there is an underlying conceptualization process, or cognitive construal, of the linguistic categories that guides the implicit associations and allows them to be both entrenched for the individual and conventionalized for the community of speakers. The conceptualization process occurs in form of a conceptual blend or conceptual metaphor.

According to the Cognitive Linguistics paradigm conceptual metaphor is a cognitive mechanism at the basis of linguistic elaboration and thought. Conceptual metaphor foresees the expression of ABSTRACT/TARGET DOMAIN IS CONCRETE/SOURCE DOMAIN (the conceptual metaphor concepts are expressed in small caps), where the abstract domain is understood in terms of the concrete domain through a set of systematic correspondences. In this approach conceptual metaphors are seen as structures and mechanisms that underlie not only specific metaphoric linguistic expressions, but also conceptualization and reason itself. For an explanation of conceptual metaphor see for example Lakoff and Johnson [13], [14], [15]; and Kövecses [16].

The IAT results suggests that the experienced relevance of what is in our visual field is yielded by the conceptual metaphors KNOWING IS SEEING, INVOLVEMENT IS CLOSENESS [15], or STRENGTH OF EFFECT IS CLOSENESS [14]. This is coherent with the ME-FIRST orientation observed by Cooper and Ross [17] and [8], which states how we prefer to consider ourselves HERE, NOW, and UP, FRONT, ACTIVE, and GOOD, rather that the opposites. What is related to LIGHT (*warmth*, *yellow,* or *brown*) is deemed to be more pleasant; therefore relevant and preferred. These concepts thus seem to serve as a guiding linguistic default construal. What we can perceive as LIGHT or WARM is pertinent because it is implicitly NEAR, and has a STRONG EFFECT.

BROWN and GREY, though unsaturated, are colors nonetheless, and color information and interpretation are what allow us to gather knowledge about our surroundings. It is in this contextual processing that the conceptual metaphor KNOWING IS SEEING represents one of our principle experiential motivations of how the mind works (see [13]). It stems from the vital function that vision plays in our reception of information of the world around us; to know something, is to see it. This conceptual metaphor is manifested in linguistic expressions like, “I *see* what you mean”. In order to see there must be sufficient light, which yields the conceptual metaphor SEEING IS LIGHT; as manifested in utterances like “in the *light* of what you are saying”. Hence, if we see color, we see, which in turn yields the primary conceptual metaphor regarding color processing, SEEING IS COLOR [18], [19], [20], [21], [22], [23]. So if LIGHT, COLOR bring about SEEING, these concepts are manifestations of something that we feel to be positive. Moreover, as living beings we thrive only if there is light. The activity of photosynthesis and the production of oxygen is fundamental for our survival. Our embodied experience of this yields LIFE IS LIGHT as manifested in, “The *light* in his eyes was still there, but it had changed” [8], [21]. These conceptual metaphors blend in the complex of metaphors that mark what is GOOD or PLEASANT—KNOWING vs. NOT KNOWING, SEEING vs. NOT SEEING, LIGHT vs. DARK, COLOR vs. LACK OF COLOR, WARM vs. COOL. We perceive tactile warmth as pleasant and desirable, this together with our synesthetic knowledge allows us to project temperature onto the visual aspect of color, and hence transfer this goodness to color warmth. This is an explanation of the associative strength of BROWN with PLEASANT over GREY.

5. Conclusions

The implicit attitudes toward the linguistic categories BROWN and GREY with the linguistic categories of PLEASANT and UNPLEASANT result to have a *moderate* associative strength between BROWN and PLEASANT. This follows the initial hypothesis that color temperature tends to guide a bilateral preference, or positive association. In past studies regarding the hue dimension in linguistic color term IAT tests, the linguistic category YELLOW received a higher evaluative strength (faster response latencies) with the linguistic category PLEASANT when compared with the categories BLUE, GREEN, or RED. BLUE was more compatible with *PLEASANT* only in comparison to RED and GREEN, not to YELLOW. GREEN was more compatible with *PLEASANT* only in comparison to RED. RED was never more compatible with *PLEASANT* in comparison to the other colors [8]. It would thus seem that the warm categories are implicitly deemed more pleasant except when compared with RED, which being more "intense", or hot, associated with *fire* and *blood*, scores a lower *D* value, or a slower latency response. Even though both BROWN and GREY are lowly saturated colors and may be associated with both negative and positive connotations, BROWN reveals a moderate associative strength with PLEASANT when compared to GREY.

A future linguistic IAT should involve the lightness/brightness dimension regarding WHITE vs. BLACK. It is logical to hypothesize WHITE as being more PLEASANT, yet, for this reason, it would be interesting to verify if the grounding of these concepts is coherent with the proposed explanation.

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Urban representation and chromatic research in the tradition of Vatican micromosaics

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1. Introduzione

Among the most singular forms of urban representation are those which, since the end of XVIII Century, began to employ the technique of the so-called micromosaic (or mosaic minute) for the production of jewelry and precious articles with the purpose of spreading throughout Europe the image of monuments and cities of Italy such as destinations *of the Grand Tour*.

Fig. 1 – Bracelet of gold and micromosaics on glass past, representing Roman Monuments, Mid-19th century, Private collection.

The mosaic technique had obtained the citizenship in the Vatican by the establishment in 1587 of the mosaic school of the Reverenda Fabbrica di San Pietro, with the task of decorating the interior of the basilica and replaying in a non-perishable form the pictorial heritage.
The objective of imitating painting had requested a specific technical research, aimed at obtaining an almost infinite chromatic range of enamels, able to simulate the results of the chromatic modulation obtained by brush.
It should also be avoided the typical gloss of enamels used in Venetian mosaic, which would have made obvious discrepancy with the painted surfaces. For that provided, at the beginning of the eighteenth century, the kild man Alessio Mattioli, developing the formulation for *scorzetta*, an opaque glass paste, based on metallic lime mortar, with which he managed to modulate a range of 68 tones derived from the *porporino* (purple), which allowed a realistic rendering of skin tones.
Despite this great technical skill, at the end of the same century, the completion of the works of decoration and reproduction threatened to leave unemployed the mosaicists of the school, which had been transformed in the institution of the *Studio del Mosaico Vaticano*.
It happened, however, that two of the most skilled and renowned of them, Cesare Aguatti and Giacomo Raffaelli, devised the so-called technique of "spun enamel". This process consists in smelting again in a crucible the blocks of vitreous enamel (the so-called *pizze*) from which they were obtained the tesserae for mural mosaics by splitting with a small hammer. Instead, by re-melting and spinning could be obtained some thin bars with 1 millimeter in cross section. These could be segmented into some tiles to compose tiny mosaics for inserting them in wide sample collection of items with very different size and importance.

So, the membership of an institutional manufacturing center allowed the mosaic workers to undertake some job orders with larger technical and financial commitment, as, for example, top-tables, paintings or fireplaces paneling.
These objects were often commissioned to serve as gifts in some important occasions of papal diplomacy, as happened to the table with the reproduction of *The Achille's shield,* donated by Pope Leo XII in 1826 at the wedding of Charles X, which paper pattern are exhibited in the Micromosaic Hall in the Vatican Museums.
So, while smaller items, purchased in the shops around piazza di Spagna by tourists on the *Grand Tour* [8], became icons of Italy and its beauties in their country of origin, the papal gifts became a vehicle so eloquent of the fame of micromosaico that many European monarchs invited the Roman mosaic workers to move to their courts in order to establish similar structures to the Vatican Mosaic Studio, whose budding were born in St. Petersburg, Paris, Naples and Milan, where, in 1804, Eugene Beauharnais, even manages to persuade Giacomo Raffaelli to accept supervision of the Milanese center and the monumental reproduction of the Leonardo's *The Last Supper*, today housed in the Minoritenkirche in Vienna.

2. The technique and its evolution.

Both the bigger (or cut) mosaic and the minute (or spun) one were born as merely reproductive processes of existing images, often painting, to which them both aspire to be like.
However, there is a fundamental difference, resulting from the fact that while the first assumes an observer placed at a considerable distance, the minute mosaic is made to be very closely looked at.
The requirement to maintain the resemblance with painting although if very closely looked at, requires an extremely meticulous precision manufacturing process.
The first step is the preparation of the *cassina*, a kind of formwork, which was originally established for small objects from a mould made of copper and, for the larger ones, of iron, later replaced by a sheet of precious material (glass paste, black Belgian marble, onyx or other semi-precious stones) excavated to obtain a basin to be filled with a paste made of gypsum, on which is possible to trace in pencil the preparatory scheme by the paper pattern, with the partition in different color zones.
They are then dug out, one at a time, and gradually filled with the mastic, a dough with a slow curing, prepared with gypsum and with cooked and uncooked linseed oil, on which each tile is carefully placed.
When the mastic has fully hardened, a process that can take several months, you can fill the gaps and polish. [7][8].
While the phases of this operating procedure are not substantially changed through time, much more complex and articulated appears the evolution carried out by chromatic research in the production of tesserae of enamel and also in the technique with which they are placed in micromosaic.
This is a research that has developed almost entirely, from the beginning in the last quarter of the eighteenth century, in a little over seventy years, and that is not easy to reconstruct, because poorly supported by archival sources. The mosaic makers, remaining themselves craftsmen rather than artists (to such an extent they sign their

works very rarely), didn't bother to document their technical advances, but, on the contrary, they guarded the secret of their tricks of the trade.
Furthermore, many items of lesser size - that is, those that were most often been used as a test field at lower risk - are now dispersed in a large number of private collections or even, as is still the case until a few decades ago, considered some simple *souvenirs*, unusual fruits of patient craftsmanship, but without any kind of artistic value.
Today, from the nucleus formed by the collections of larger and precious objects (represented by the areas dedicated to micromosaics in the Hermitage in St. Petersburg, by the Gilbert Collection in the Victoria and Albert Museum of London [1][5] and, in Rome, by the Savelli collection[6] and the Petochi collection [2][3], subsequently merged into the Hall of micromosaic in Vatican Museums [1][4]- we are witnessing a process of regrouping of existing assets and a dissemination of knowledge about micromosaic and its history. That his also happened thanks to some important exhibitions, fit out since the two last decades of the twentieth century.
Analyzing the mosaic production so became available, historians have outlined its periodization, marked mainly by technical innovations, whose exact dating and authorship show, however, for the reasons already described, some margins of uncertainty.

Fig. 2 – G. Raffaelli, Snuffbox cover (Ø 7 cm) with *Colosseum, 1791* (Vatican Museums, inv. 53234)

[1] The study of Vatican Museums mosaics has formed an essential part of this research that, in absence of the kind availability and the invaluable assistance of prof. A. Paolucci, prof. F. Buranelli and prof. G. Cornini, I wouldn't have been able to carry out.

The phase of the beginning, dominated by the personality of Giacomo Raffaelli and Cesare Aguatti and generally held to coincide with the last quarter of the eighteenth century, in fact, sees the prevalent use of tiles made from monochrome bars, square or, at most, rectangular, but always arranged in parallel or concentric to the perimeter of each area to be patterned lines.
Many recent studies, thanks to the discovery of the inventory, writtem by himself, of the bars owned by Raffaelli, have shown that the palette offered, already at the start, a wide selection. The inventory includes indeed 2827 bars, divided into 872 containers corresponding to the different tones of the 18 basic colors, among which predominates quantitatively the flesh-colored (more than 800 rods), while the green color comes as the most varied, with 77 different shades [8].

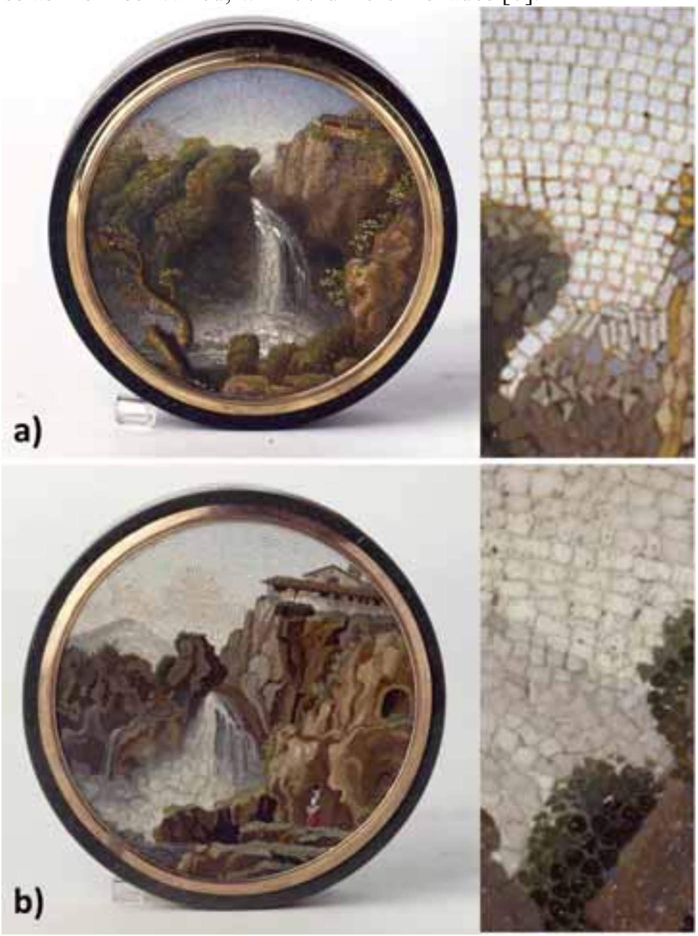

Fig. 2 – Comparison between two plaques, dating from first (a) and second (b) half of 19th century, both portraying *Cascate di Tivoli* (Waterfalls in Tivoli) ,Vaticans Museum, inv. nn. 52249 and 52257.

The second phase is the one in which the invention by Antonio Aguatti (who lived in the second half of the nineteenth century and died in 1846) of the so-called *malmischiato*, obtained by spinning, bars with variegated colors, leads the art of micromosaic to its full maturity, endlessly expanding the range of colors at its

disposal, enhanced with the introduction by Gioacchino Barberi of human figures on a black background monochrome.
In this period, the tesserae show different formats, often irregular or curved; in addition, they are no longer arranged in regular lines, but freely, so as to highlight plastic or of *chiaroscuro* aspects of the figures, with results of remarkable pictorial naturalism.
The beginning of the third phase is considered coinciding with the invention in 1837 by Michelangelo Barberi and Giuseppe Mattia of the so-called *colori a soffio* (colours by blowing), obtained using in the spinning the same lamp for welds used by goldsmiths, powered with a blacksmith's bellows. The bars made by new technique show colours with a particular vividness and a chromatic spectrum much broader than that obtained in furnace. This spectrum corresponds to the one still in the possession of the Studio del Mosaico Vaticano, which, for its production, conservation and restoration of mosaics and micromosaics activities, can now boast a range of 28,000 different color variations, the so-called *munizioni* (ammunitions) *della Fabbrica di San Pietro*.

3. Iconographic themes and chromatic research

The illustrated periodization is structured according to the main stages of the technical experimentation by mosaic artists and fits only partially with the scanning time within which it can be read the evolution of the mosaic art in the field iconographic, whose recurring themes in each period show the evident adherence to the myths and ideals of their time.
Nevertheless, many connections are discernible between represented contents and technical resources used by the mosaic artists from time to time.

If we analyze the iconographic themes recurring in the oldest objects in micro-mosaic, it can detect the use of those which at the time were to be regarded as true icons of classical antiquity, meaningful symbols of a world in which neoclassical culture recognise the golden age of humanity.
Are included in this category, as well as numerous reproductions of the Apollo Belvedere, the famous *Plinio's doves*, recurring subject, probably because very required after the discovery at Villa Adriana of a mosaic with same representation.
The repertoire of mosaic artists is implemented soon, thanks to the production of eighteenth-century views and engravings, often inspired by archaeological findings, that animate the cultural debate at that time.
So, the sites of the Pontina countryside or the Roman ruins become real iconographic *topoi*, surrounded by natural landscapes, dominated by the softer tones of green and almost suspended on homogeneous backgrounds, composed of square tiles, cerulean blue light coloured, as if the representation devoid of spatial depth of the sky constitutes the more appropriate background to the beyond time condition of the buildings, depicted in shades ranging from golden yellow and gray-brown.
In the next phase, which coincides chronologically with the age of the Restoration, the micromosaic makers expand their repertoire, in which archeology remains an indispensable source of inspiration, with the representation of monuments of Christianity.

Fig. 4 – Small rectangular plaque in glass past with micromosaic, portraying a view of piazza Duomo in Milan, second half of 19th century, Vatican Museums inv. 53410.

Fig. 5 – Small plaque (cm 6,7 x 4,2) attributed to N. De Vecchis (first half of 19th century) and representing a *Compianto funebre* (Funeral lamentation), housed in Vatican Museums, inv. 54951.

What is new, however, is the placement of the subjects in clearly determined urban settings, sometimes impregnated with the spirit of Romanticism historicist.
In a few mosaic works of that period there is also a certain inclination to the elegy and iconographic narration, as in the small plaque, attributed to N. De Vecchis, that G. Cornini first identified as a representation of a *Compianto funebre* (Funeral lamentation) [4] .
That is a scene imbued with "*foscoliana introspezione* (Foscolo's introspection)", but linked to a mournful event perfectly identifiable in the chronicles of the time, the untimely death of a young English woman, whose iconographic elements present in the work (the blond hair and the style of the clothes of the figure weeping, the dog) give unequivocal clues, together with the elements exact spatial location (the cypresses the Protestant Cemetery in Rome and the Cestius's pyramid on the horizon).
The same descriptive precision and identification of the place characterizes also the picture in mosaic minute, manufactured in Lombardy, now housed in the Casa Museo Mario Praz in Rome, and representing the Arco della Pace, landmark of an extended system of urban and architectural interventions, only in part realized, that was supposed to transform the Teresian Milan in the Napoleonic capital of the Kingdom of Italy.

Fig. 6 – Picture in micromosaic on Belgian black marble, representing *Arco della Pace* in Milan (Mid-19th-century), housed in Casa Museo Mario Praz in Rome, in comparison with the engraving by L. Bramati, 1840, Civica Raccolta di Stampe "A. Bertarelli", Milan, rep. P.V. m 5-19.

The iconographic source was the engraving by Luigi Bramati in 1840's version (which differs, in comparison with the previous one by the same author, because the presence of low barriers in place of the metallic fence), showing the arc, with two lateral tollgates, inserted in the urban context of Piazza Sempione.
The unknown mosaic maker was certainly equipped with architectural knowledge, as the warping of the tesserae reveals the differentiation between the masonry,

campite with rectangular tiles of constant size, and the realization of the parts relating to the system trilithic.
Equally accurate appears the representation of the syntax of the architectural orders, entrusted to the use of bars in one piece and in different colors, juxtaposed to simulate the contrast light-shadow grooves of columns and moldings of frames.
In the transition from black and white engraving to colorful mosaic, the *malmischiato* - already adopted by Aguatti in naturalistic rendering of furry animals – here has been used only in a small portion of the bas-reliefs on the surface of the arch and tollgates, while the remaining is largely made with a thorough chromatic modulation in pink-beige, similar to the rich chromatic shade prepared by the Vatican Studio for the flesh tones mosaic representation.
The trend towards the use of bar in one piece, with strong contrast with adjacent areas, with the purpose of identifying the individual architectural elements or marking edges of buildings, together with the use of tiles in various format for the plastic rendering of the wall surfaces, are detectable characteristics also in much smaller artifacts, as we can see in a pair of earrings, always of the first half of nineteenth century, belonging to a private collection and portraying Santa Maria in Cosmedin and the Cestius's pyramid.

Fig. 7 – Earrings of gold and micromosaics on glass past, representing Santa Maria in Cosmedin and Cestius' pyramid in Rome, First half of 19th century, Private collection.

In the mosaics of the following period, the bar in one piece will be used, rather than to accentuate individual architectural elements, to reduce the time of realization.
In some measure, that seems the case of the probably manufactured in Milan broch, included in a private collection and representing the *quadriportico* of the san Lorenzo's Columns in Milan, which C. Stefani [8], dated as before the discovery of *malmischiato*, a dating that who writes can't totally agree on.
In fact, the mosaic artist seems to have used as a source the engraving of 1828 by G. Migliara and G. Elena, which were carried out, at that time, many redrawing and reprints; by this, he retraced with precision both the framing (in the incisions earlier, the quadriportico is instead always seen from the opposite side) and the perspective construction, of which proposes even the *chiaroscuro* effects, but certainly integrated by observations from the true, such as, for example, that relating to the

Crucifixion, depicted inside the votive aedicula, which, in every image of the time and of the following decade, appears instead closed by wooden doors.

Fig. 8 – Comparison between the engraving by G. Migliara and G. Elena representig a view of *Colonne di S. Lorenzo in Milano*, 1828, (Civica Raccolta di Stampe "A. Bertarelli" Milan, rep. P.V. m. 7-8) and the broch in gold and micromosaic with the same framing, second half of 19th century, Private collection.

Despite the unquestionable executive summariness, detectable almost by exclusive use of long bars in filling the residential building curtain on the left, the artifact instead shows some attention and originality in the color rendering, using quite saturated tones of reddish-brown typical of old Lombard bricks.
But, it is in the best performances of the mid-nineteenth century, especially those related to Michelangelo Barberi and his team, that the research on the color, as a fundamental descriptive element for the town and landscape representation by spun mosaic, finds its most aware expression.
Are the Barberi's skies, with their opalescent heavenly, obtained thanks to the new technique of the *colori da soffio* and with their dizzying effect of depth, to be the unifying element of the scenic landmarks depicted in his spectacular tables.
The most famous of these is the one exactly titled *The beautiful sky of Italy*, commissioned by Tsar Nicholas I and now included in the Gilbert Collection at the Victoria and Albert Museum. With this table Barberi won the coveted Council Prize, the only gold medal awarded to the Papal State at the 1851 Great Exhibition of the Works of Industry of All Nations at the Crystal Palace in London [5].

Fig.9 – Snuffbox in gold, tortoiseshell and cover with micromosaic (cm 5,3 x 3,5) representing *Veduta notturna del Colosseo* (Night view of the Colosseum), Mid-19th century, housed in Vatican Museums inv. 53230.

The same masterful use of color in portraying the atmosphere seems to drive also the composition of several views by moonlight, sometimes exhibited in opposition to daytime views, with which M. Barberi inaugurated a genre destined to codify the romantic *topos* of the nocturnal representations of Roman antiquities .
Among them, the snuffbox with plaque representing the *Veduta notturna del Colosseo* (Night view of the Colosseum), preserved in the Vatican Museums [4], is characterized by an eerie chromatic force, obtained with the contrast between the tesserae in dark bleu used for the sky and the lighting effects, created by yellow-very light-green touches, in order to stress the presence of clouds around the pure white silhouette of the moon.

Fig. 10 – Paperweight in Belgian black marble and micromosaic (cm 8 x 5,6) representing *Il Tevere presso Castel Sant'Angelo* (The Tiber near Castel Sant'Angelo), Last quarter of XIX century, housed in Vatican Museums inv. 53288.

4. Conclusions

Although the important legacy of the Barberi's lesson, in the following decades the tradition of tiny mosaic seems to lose its booster shot both in iconographic and in chromatic field.

The production, indeed, crystallizes in a repetition of manieristic compositions and already tried technical solutions, with the exception constituted by small paperweight with the representation *Il Tevere presso Castel Sant'Angelo.*
In this small mosaic a widely known urban glimpse urban is rekindled by the adoption of an unusual chromatism, in which the use of pure yellow highlights seems to want to link directly to the van Gogh's experimentation of colors in the representation of landscape.

Even the chromatic sensitivity of the Art Nouveau period, while suggesting to the mosaic art in small some interesting ideas isuggested by observations of the animal world, which has produced a few elegant representations of dragonflies, fails to bring new life to the field of urban view, which fall into line with the canons of representation of gender and under a purely technical reproduction.

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The Colour of Maya Architecture

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1. Introduction

Due to the almost complete disappearance of colours from the architectural surfaces of the pre-Columbian cultures of Mesoamerica, the importance of the use of colours that added legibility, vibrance and mystical meaning to statues, low reliefs and architecture in general, is often overlooked. Unfortunately, this happens both among common people as well as among scholars. Today, colourless for the most part[1], low reliefs are very difficult to perceive by the untrained eye and when they are, scenes of Mayan life are mute in their well-ordered chaotic art made of traces, curls and dots. As it happens in each and every culture based on primordial tradition, colours are a part of a series of symbols that go beyond simple decoration. Further in the paper, we will see that the colour blue, for example, is not 'only' a colour but it suggests a deeper reality. Staring at such traces calls the watcher to the famous puzzle game of connecting the dots to discover the hidden figure. The peculiar light of the tropical regions of Mexico flat the image so much that it is quite impossible to mark the whitish surface of the intricate low reliefs. Colours, as much as a critical and disciplined mind are the key to being able to appreciate the still life's scenes of the Maya. The paper will explain materials and technique of Maya color production as well as their use and meaning both in everyday's life and ceremonial rituals.

2. On the perceiving of colours

One would be amazed on how mayan cities were a dazzling display of colours, these, also worn as textiles, ornaments and body paints were not a mere decoration but a meaning of identity.
Today as a physical effect, colour is perceived as a vibration in the electromagnetic resonance of light. The visible spectrum for human eyes lies between the range from red to blue, at wavelenghts between 360 and 760 nm. Processed by the brain, the sensation of light is a complex intersextion of wavelenght, reception and neural transmission. From the sensory point of view, colour may be perceived through three different attributes such as brightness, hue and saturation; while brightness can be expressed as a total energy value and characterizes the gradations from dark to light, hue is dependent on the wavelength of light and contributes to label a certain colour and saturation defines the purity and intensity of a certain hue.
Setting aside the physiological nature and the perceiving processes of light and colour, in maya coulture, colours formed an unique entity and maintained a strong relation to the material they were found in nature or were made of, thus *yax*, the blue-green, confers the sense of 'new' or 'first' in reference to the hue of fresh foliage.[2] In general, colour was applied according to the material of the object portrayed, however, colour was also used symbolically.[3] In a certain way, colour gave life to matter so that the act of removing it from an architecture was a way to 'kill' it.

Fig. 1 – Kohunlich, Mexico, *Templo de los Mascarones*,

	Language			
Colours	Classic Ch.orti'	Common Maya	Material	Symbolism/Meaning
Blacks	*ik'*	**ejq'*	Carbon black, manganese oxides and hydroxides	west,difficult,supernatural,fear
Whites	*sak*	**saq*	calcium carbonate, aragonitic, calcitic and dolomitic limestones	north,clear,artificial,skill
Reds	*chak*	**kaq*	hematite minerals	east,hot,blood,great,rage
Yellows	*k'an*	**q'an*	geothite minerals	south,vegetation,ripe
Blues	*yax*	**ra'x*	azurite, palygorskite clay mixed with indigo	center,clear,moist,devine,first
Greens	*yax*	**ra'x*	malachite	center,clear,moist,devine,first

Tab. 1 – Maya colours, components and meanings

Fig. 2 – Copán, Honduras, Late Classic Period, *Rosalila,* Life-size reconstruction of the temple at the site museum of Copán

3. Painted architecture

In pre-Columbian mesoamerica cultures, colour was an important aspect of both architecture and monumental sculpture; paint was carefully considered before construction and was an integral part of the creative process of buildings and sculptures. Colour was perceived and functioned less as a decoration than as a vehicle for symbolic meanings.[4] Maya culture, but this may be said of almost every pre-Columbian cultures, was based on a very specific and highly regarded tradition full of rites, customs and habits that permeated every aspect of society. Every citizen, whether king, noble, priest or commoner, everyone had to contribute even through bloodletting self-sacrifices to the preservation of the world through cosmic cycles.[5] A quite common idea among scholars is that colours were also associated to cosmic directions, that is red for the east.; black for the west; yellow for the south; white for the north and blue-green for the center. Yet, the presence of a center suggests that the same colours are not a simple expression of the four cardinal points but are, as any traditional culture, an expression of a cosmic movement or cycle of existence, thus red-east is related to the spring equinox; black-west is related to the autumn equinox; yellow-south is related to the summer solstice and white-north to the winter solstice while blue-green is the center, the unmovable Priciple.[6] In Preclassic architecture, the extensive use of red, black and white shifted to the polychromy paint of the Late Preclassic which was used on modeled stucco and decorations of the pyramid facades. In the Classic period, polychrome facades are replaced by the use of selected colours such as either white or red for the external surfaces and the interiors walls, those could also be painted with geometrical white and red patterns; polychromy was reserved for interior figural murals or architectural sculptures.

Fig.3 – Chichen Itza, Mexico, Late Classic Period, *Templo de los Jaguaros,*Top, the Temple as it appears today. Bottom, colour reconstruction based on found evidence

Fig.4 – Chichen Itza, Mexico, Late Classic Period, *Los Osarios*, Top, the Temple as it appears today. Bottom, colour reconstruction based on found evidence

4. Maya colours

Most of the paints and pigments of the Maya tradition were made using mineral pigments of inorganic origin, lakes and organic compounds and were used in two ways, naturalistically and symbolically.[7] Lakes are basically pigments manufactured by precipitating dyes with an inert binder, or ‘mordant’ such as clay, chalk or gypsum. Paints were made by collecting pigments such as minerals or coloured earths and had to undergo a long series of washing to removes impurities and concentrate the colour. Almost all maya paints used water as a vehicle with the addiction from time to time of various clays, lime slurries and vegetal gums.[8] Recent works[9] have revealed the use of carbon black for black, hematite for red, geothite for yellow and both or either calcium carbonate and gypsum for white.

Blacks

Black pigment came from two different sources, one organic, the other mineral. Carbon black, an organic material, appears to have been the dominant black pigment and was obtained from burning tree resins or burnt bone and produces a deep black pigment. The inorganic counterpart was used primary for pottery and was made from manganese oxides and hydroxides.[10]Black does not appear to have been used in polychrome color schemes, although it remains prominent in the linear style and as working drawing.

Whites

White was provided by the lime of stucco, its quality was altered by the purity of the lime source and by the mixing of additional material into the plaster such as bark extracts. The main source for white paint came from calcium carbonate such as, depending on availability and location, aragonitic, calcitic and dolomitic limestones.

Reds and Browns

Reds come from hematite a closely related iron oxide mineral. Hematites and other iron based minerals are found I abundance throughout the region and, based on purity and quantity, produce colors from dark orange/browns through bright reds and pinks.

Yellows and Ochres

Yellows come from geothite, a closely related iron oxide mineral just like the hematite. They come in colours that vary from yellow to brown depending on its degree of hydration, crystallinity and purity. Both geothite and hematite also occur as ochers, earthly forms of the minerals mixed with clay.[11]

Blues

Blues came from azurite and indigo. Azurite is a copper carbonite hydroxide found in secondary copper ore deposits. Over time, azurite was used less and less and had been replaced by Maya blue which is a lake made by dyeing white palygorskite clay with indigo.[12] Maya blue is a very stable paint, unaffected by acids, alkalis, solvents, oxidants, reducing agents, biocorrosion or moderate heat.[13]

Greens

Greens come from malachite a copper carbonate hydroxide that as the azurite, is found in secondary copper ore deposits. Green in colour, its shades can be manipulated by altering the grind of the pigment.[14]

5. Conclusions

In its time, Maya architecture appeared as a marvellous explosion of colours that provided a greater sense of completeness. Colour was meant to emphasize characters and meanings of the reliefs, distinguishing the various and multiple aspects of maya tradition or the inner aspects of their faith and religious rituals. In architecture, colours were not meant only as simple paint to enliven forms, identifying objects, people and gods, but as a way to attribute to its vessel both natural and supernatural values, to enstablish an indissoluble link between the maya traditional civilization and the cosmogony and beliefs of the perpetuation of cosmic cycles. As this is true for architecture and wall painting, it is not always so for the colorizing of statues on which colour may have been purely decorative.

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[1] [1] Most pre-Columbian painted works have been damaged over time by humidity, fungus, vegetation, and general weathering. Pg.61

[2] [1] Pg.16

[3] [2] For example, feathers, water and jade were given a 'natutal' blue, flesh was a 'natural' red; sacred or supernatural objects were given a 'symbolic' blue. Pg.46

[4] [3] Pg.173

[5] [4] Ritualised sacrifice was usually performed in public by religious or political leaders piercing a soft body part, most commonly the tongue, ear or foreskin. The blood was then collected and either smeared on an idol, burned onflames or mixed in the bread dough, baked and eaten. Pg.2

[6] [5] Pp. 57-67, 96-100

[7] [6] The low reliefs from the Great Vestibule of Tula reveal "a well organized colour scheme in which red is used for background and some ornaments; blue indicates feathers and jade and turquoise ornaments; yellow denotes other feathers, weapons and jewels; white also indicates feathers as well as eyes, teeth, and cotton clothing; skin is pinkish-ochre; and black is used to outline motifs and to make them stand out." Pg.115

[8] [7] Pp.23-23.

[9] [8]

[10] [9] Pp. 40-41

[11] [9] Pg.37

[12] [10] There is a wood or plant from which indigo is made, which the natives of these provinces formerly employed for a blue dye or paint, hence the Spaniards availed themselves of it and started large plantations, that they have come to make large quantities in the provinces. Pp. 117-118

[13] [11] Pg. 223

[14] [12] Fine grinds result in a very light green while coarser grinds result in darker hues. Pg. 8

Social Spectrum; Mapping Rational, Empirical and Metaphysical Relationships with Colour.

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Introduction: Colour as Affordance

If wavelength is viewed as an affordance related to colour then the synaesthetic response for; a day of the week; a graphic form; a sound; a taste, a smell; a texture and a story can be others. However, rather like the table and the chair they can be interchangeable so can colour relationships, aptly demonstrated by the opposing characteristics of the Munker-White Effect and Colour Constancy. How, why, where, when and to what end colour is part of our ecosystem and how is it experienced and articulated? These are the questions raised.

1001 Haphazard Colours is a project that began in 1998 as a school residency reaching a ‘temporary’ conclusion in 2015. 1001+ stories were collected; part of a digital installation exploring the meaning and significance of colours. Some contributions are short and concise others deeply personal; ranging from a team’s kit to the colour of the sky on the night of liberation in 1945. The youngest contributors are pre-school the oldest well beyond retirement. The key is a simple theme, a colour of significance that opens the door of memory and symbolism and seeks inclusivity of age, gender and ethnicity.

OrbisTempusColorem34 is a new web-based work, completed in 2015. It expresses 34 global time-zones and 7 bands of time mediated through colour. The seven bands of time reference ways time is delineate: DayTime, WeekTime, MonthTime, YearTime, HomoSapienTime, EarthTime and UniverseTime.

The world is organised into time zones bearing a partial relationship to the position of the sun in the sky; however, this is a partial relationship. What time zone to join is often a political decision to unify a territory partially determined by longitude and partially in relation to political geography. All times are crushed together at the North/South Poles; what time is determined by the direction you look.

Presentation
In this presentation there will be an examination of 2 works forming part of an ArtsD programme at the University of Middlesex, entitled 'Social Spectrum: Rational, Empirical and Metaphysical Relationships with Colour'.

The 2 works to be discussed are:

1. **1001 Haphazard Colours** is a project that began in 1998 as a school residency reaching a 'temporary' conclusion in 2015. 1001+ stories were collected. Some contributions are short and concise others deeply personal; ranging from a [sport] team's kit to the colour of the sky on the night of liberation in 1945. The key is a simple theme, a colour of significance that opens the door to memory and symbolism.

The second work:

2. **OrbisTempusColorem34 is** a new web-based work, completed in 2015. It expresses 34 global time-zones vertically and 7 bands of time horizontally mediated through colour. The horizontal bands reference ways time is delineate: DayTime, WeekTime, MonthTime, YearTime, HomoSapienTime, EarthTime and UniverseTime.

1001 Haphazard Colours
A Local/National Social/Political Context
The school residency was part of an inner city Regeneration project (SRB). SRB was set up in 1994 to bring together a variety of programmes and initiatives from several Government departments. The priority was to enhance the quality of life in areas of need by reducing the gap between deprived and other areas. Portsmouth's bid included 'the arts' as active cultural engagement to raise aspirations.

Reports into social conditions while being worthy and thoughtful the underlying politics were highly culturally biased [I], the position was: there is something wrong with the poor and in response the rich and educated will put it right. It's with some irony that during this period it was the rich and educated who where raping society for all they could get out of it while storing their gained economic capital in the haven of international art markets and property debt.

Along with Power and Capital in any class systems and the 'suitable taste' that goes with it; whether based on wealth, birth or cultural capital accrued through education and privilege or simply the crude exercising of power, there is the institutionalisation of 'those who know and understand' and 'those who do not.' Along with marginalisation of those who are 'other' there is marginalisation of their sensual environment.

So what about colour? The 'usual' context for understanding colour relates to wavelength of light; but colour is much more complicated than this. Newton organised colour into the seven bands in the rainbow: Why seven? The seven

colours relate to the already established seven notes of the musical scale. It's not a 'reality' it's based on a pre-existing model for the expression of harmonic pattern in western music. Goethe's colour wheel contains six basic colours from which all other colours are mixed; but where is the geometry to colour; it's arbitrarily placed in a wheel? Newton searched for a mathematical understanding; Goethe believed there were much more complex interactions at play; physical, chemical and physiological marking the origin of the debate between the arts, psychology, neuroscience and the semantics of colour.
In 1969 American anthropologist Overton Brent Berlin working with linguist Paul Kay published 'Basic Color Terms: Their Universality and Evolution' that became a highly influential reference for those studying the relationship between colour in a linguistic/cultural context. Their basic range of (English) colours terms are: Black, White, Grey, Red, Green, Blue, Yellow, Orange, Pink, Purple and Brown. Their aim was to establish a universal set of colour terms that could be transposed and matched across cultural environments determining an evolutionary process. The conclusions where represented as a hierarchy showing that European languages had more 'basic colour terms' than languages from more 'under-developed' peoples; there are exception e.g. *Thai, Japanese, Korean, Zuni (New Mexico), Jekri (Nigeria)*[3].

The crude assumption is; in many parts of the world, peoples have language systems that are not as 'evolved' in colour terms as the high scoring European languages. However, the methodology has been convincingly dissected and conclusions shown to be highly flawed [II]. Even the term 'basic color term' is an unresolved matter [III].

1001 Haphazard Colours is the antithesis of Berlin and Kay's hierarchy of exclusion. There is the choosing of a colour from a prescribed 24bit RGB palette (Berlin and Kay asked participants to make judgements from Munsell colour chips) but the choice is a reference; not an exact science of colour matching. It is an approximate medium for meaning not a statement of fact. In simplistic terms the colour model is RGB; in a much more important sense the colour model is based on memory and narrative. The choices of hue are important for their symbolic value; the actualities of the colours are in embedded memories. This is not an abrogation of colour science it is a recognition that colour is more complex than any particular delimited colour system[IV]. It bears more relationship with Goethe's interpretation of colour having 3 relational manifestations; physical, chemical and physiological rather than Newton's numeric relationship with wavelength and its extrapolation into a neuro-scientific approach which takes much from an engrained dualistic position.

My focal argument is that colour is part of the complex environment and ecology within which we operate as active participant not principally a science of numbers in digital presentation or as a set of aesthetic rules determined by haphazard cultural power and predisposition. In 'The Ecological Approach to Visual Perception' by American psychologist James J. Gibson published in 1986 he states:

‘The man-in-the street has always supposed that the colors of objects are one thing, whereas the colors of a rainbow or a sunset or an oil-slick are a different matter. He sees the color of the surface in the surface, although he may see other colors that appear to be in the light. But this simple fellow has been told he is wrong ever since Newton's discovery of spectral wavelengths, for colors are only in the light, not in the objects. Even more, he is told by physical optics and physiological optics that colors are only in him since the light consists of waves .. . The poor man is bewildered but he goes on seeing colors in surfaces. More exactly, he sees very much the same color in the same surface despite change in the amount, kind, and direction of the illumination falling on it. The light is variant, the color is invariant, so of course he sees the color in the surface, not in the light.’ [5]

Costall. A. (2014) in ‘Does colour matter? An affordance perspective.’ Sheds further light on Gibson’s perspective.
‘What is not so obvious from the preceding quotation, however, is that Gibson was not claiming that colour is physical rather than mental. Gibson was attempting to undermine the very dualism of the physical and mental (along with many other dualisms, such as knower vs. known, body vs. mind, and biology vs. culture). Given how ingrained these dualisms have become within the western tradition, ...’ [6]

Gibson gives a clear explanation of an affordance in [to] perceive an affordance is not to classify an object:

“The fact that a stone is a missile does not imply that it cannot be other things as well. It can be a paperweight, a bookend, a hammer, or a pendulum bob. It can be piled on another rock to make a cairn or a stone wall. These affordances are all consistent with one another. The differences between them are not clear-cut, and the arbitrary names by which they are called do not count for perception. If you know what can be done with a graspable detached object, what it can be used for, you can call it whatever you please.

The theory of affordances rescues us from the philosophical muddle of assuming fixed classes of objects, each defined by its common features and then given a name. As Ludwig Wittgenstein knew, you cannot specify the necessary and sufficient features of the class of things to which a name is given. They have only a “family resemblance.” But this does not mean you cannot learn how to use things and perceive their uses. You do not have to classify and label things in order to perceive what they afford.

An important fact about the affordances of the environment is that they are in a sense objective, real, and physical, unlike values and meanings, which are often supposed to be subjective, phenomenal, and mental. But, actually, an affordance is neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of *behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer.”* [7]

The contributions in 1001 Haphazard Colours therefore are to be seen and heard in their own terms; they are firstly in relation to the contributor; they are a particular perspective. They may conform to a collective norm; they may not. They must cross sensational and experiential boundaries and at times stand alone, it naturally crosses cultural boundaries in aesthetic and taste. There is the concrete nature of a colour that is chosen, a colour that exists momentarily on a screen, there is the rationalisation of a choice through finding and ascribing meaning and there is the mathematical system that makes it appear through a colour making tool; but the metaphysics are the memory, the love, the hate, the joy, the feeling and the humanity articulated through narrative and in relation to.

OrbisTempusColorem34

OrbisTempusColorem explicitly explores time however the interweaving of the rational, empirical and metaphysical persists. We all know [believe we know] that time is relative; Einstein theorised it was so and atomic clocks travelling at high speed on aeroplanes have confirmed it. Colour also is relative; the Munker-White effect and Colour Constancy demonstrate this in complementary ways. There is also the Red-Blue shift when objects are either moving away or towards us and there are differences between colours illuminated from an external source and those that are radiated from illuminating sources. The colour of Illuminated objects change with the intensity of light either washing it into paleness with high intensity or lowering the tone in low light intensity. Hue, Saturation, Tone and Brightness are affected by modifying qualities: Material surface qualities [V], After-Image, the condition called Colour Blindness and the condition known as Synaesthesia and environmental conditions. Colour is a relational condition mediated through all of these. It is also mediated by the gamut afforded by variable conditions. Lay over this cognitive bias and/or cultural or personal predisposition and the way we are in relation to colour is very easily described as complex. Colour is an affordance of ‘visible light’ but this is part of an infinite ‘invisible’ electromagnetic spectrum which begs the question: ‘If we could see using a wider range of wavelengths would it reveal colours as yet hidden?’

Similarly time is far more complex than Einstein’s description; there is the long, never ending minute and the all too brief year; maybe related to pain or pleasure or the converse in a masochistic view. Einstein’s relativity describes the relationship of space-time and the speed of light in relation to big things but apparently breaks down in relation to small things at a quantum level. The beginning and ending of time in a quantifiable sense is confined between big bangs and crunches but we are still left to speculate what was before and what will be after. Emmanuel Kant in Critique of Pure Reason (1781) extensively examines the question of infinity of time and found equally compelling argument in favour and against.

*‘ His argument for the thesis was that if the universe **did not** have a beginning, there would be an infinite period of time before any event, which he considered absurd. The argument for the antithesis was that if the universe **had** a beginning, there would be an infinite period of time before it, so why should the universe begin at any one particular time?’*[8]

Multi-verses or Meta-verses do not get us any closer to resolving these fundamental questions it merely delays to beyond the latest horizon. However there is no doubt there is an experience of time and an individual and collective memory of time.

Time became a pragmatic national and global matter with the ability to travel at speeds faster than a trotting horse (e.g. Railways) and with rise of international trade across the oceans in the 15th Century.

> *‘As more and more sailing vessels set out to conquer or explore new territories, to wage war, or to ferry gold and commodities between foreign lands, the wealth of nations floated upon the oceans. And still no ship owned a reliable means for establishing her whereabouts. In consequence, untold numbers of sailors died when their destinations suddenly loomed out of the sea and took them by surprise.’* [9]

Sailing was a hazardous business fraught with uncertainty and dread [VI]. The key to global positioning of a ship was to be able to accurately calculate longitude; a problem finally overcome with John Harrison’s (1693 - 1776) timekeeper H4 built in 1759. H4 and marine chronometer successors made time a global institution. The development of empirical methods to measure and calculate time has been continuous to the point where we have a number of ‘world clocks’ striving for superiority and ascendency.

Ships, cars and pedestrians through the use of GPS can, to within meters, know where they are. The lattice of longitude and latitude networks the globe with imaginary lines that are set with astounding accuracy. With the combination of more accurate machines tracking relative solar position and numeric calculations projecting this into the future time seems to have been locked into a rigid global matrix of World Standard Time. The politics of time however is much messier.

World Standard Time Zones are arranged in ±1 hour intervals calculated from the 0° prime meridian or 0^0 UTC (Coordinated Universal Time) although its national governments that unilaterally decide which time zone they wish to be in. Some create their own divisions e.g. ±:30hrs or ±:15 minutes. Some then make adjustment related to spring and autumn; ±1 hrs forward and back. It depends upon what is seen as being most appropriate for their particular circumstances. Many cities on the same longitude therefore are in different time zones; 'what time' is a political decision. Which time zone to join is a strategy to unify a political territory partially determined by position in relation to longitude, and partially in relation to political geography. 24 hours in a day; 34+ timezones. Venezuela although sharing longitude with much of the United States shares no timezone with it. The neat rational numerics of time break down in response to national agendas. The lines of time swerve left and right and create isolated islands of time based upon national imperatives.

OrbisTempusColorem abandons direct reference to the numerics of time. These are replaced by colour [VII] but the empirical relationships are maintained using these alternative sets of values. The matrix of one colour against another creates interaction in the manner of Albers 'Interactions of Colour' and the Munker-White effect; visually there is ambiguity between the empirical values and experience. There is a pulse that denotes a division but this isn't referenced to a single origin; it has internal origins from each time-band; but each colour is in relation to the colour aside, above and below it. The metaphysics of time are what remain; the passage of time as an unresolved infinite poetic. HumanTime, EarthTime and UniverseTime appear static; there is a global contemporaneity that positions all of humanity in the same place.

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Notes

[I] A Lifelong Learning report published in December 1999 'LEARNING ELEMENTS OF THE SINGLE REGENERATION BUDGET' had as part of its main conclusions:

- in disadvantaged communities there is a powerful link between low levels of attainment and a lack of motivation towards, and participation in, learning activities;
- the education and training system is confusing: fragmentation is a barrier to participation;
- in many areas the lack of locally available provision can be a barrier;
- many children's difficulties with basic skills are associated with their parents' limited literacy and numeracy – reflected in a host of family literacy schemes.

[II] Saunders B. A. C. Van Brakel J. (1997) Are there nontrivial constraints on colour categorization? BEHAVIORAL AND BRAIN SCIENCES 20, 167–228 Printed in the US
Despite the general acclaim for the theory, most detailed reviews of Berlin and Kay (1969) were critical of their methods of gathering and/or presenting data. There is an appearance of sloppiness that cannot but reduce one's confidence in their conclusions (see Durbin 1972; Hickerson 1971; and Newcomer & Faris 1971).3 For example, apart from many printing errors and mislabelled colours in the mapping diagrams, there were also ethnographic errors and phonemic mistranscriptions. No straightforward information on the informant sample was provided and the choice of languages was not justified. In their use of data from the literature, Berlin and Kay seem to have used whatever came to hand. In reviewing the methodology and nature of the data, Durbin (1972, p. 259) concluded "the reliability and validity of the experiments are zero.".... ... Finally, although Berlin and/or Kay published various amendations to their theory, in particular to introduce more possible evolutionary sequences (Berlin & Berlin 1975; Kay 1975; Kay et al. 1991a), they have never addressed issues raised by their critics. In sections 4.3, 5.3, and 6.2 we present a range of empirical evidence that further undermines the validity, not only of Berlin and Kay's (1969) theory, but of their whole approach. [4].

[III] Saunders B. A. C. Van Brakel J. (1997) Are there nontrivial constraints on colour categorization?

BEHAVIORAL AND BRAIN SCIENCES 20, 167–228 Printed in the USA.
In many disciplines Berlin and Kay's (1969) Basic Color Terms is cited as support for the cross-cultural universality of a fixed number of basic colour categories. The exact meaning of basic colour terms (henceforth BCTs) has never been spelled out. Here is how BCTs might be understood in different contexts. The referent could be a set of colour chips (colour-in-the-world), a set of neurons in the brain or a functionally defined term in language-of-thought (colour-in-the-head), words in different languages labelling basic colours (colour semantics), or the experience or sensation associated with basic colour categories (phenomenal colour). As basic colours are claimed to be universals, the exact referent of a BCT is irrelevant because all levels are connected by linking propositions standing in one-to-one correspondence. A BCT names it all.

[IV] Devine.K for example Munsell, RGB, CMYK, HSL, NCS, HSV, CIELAB etc and amy other mechanically, electronically based system.

[V] Devine.K e.g. smoothness, roughness, lumpiness, wetness, prickliness etc...

[VI] Sobel, D. (2005) Longitude. Fourth Estate. London.
Launched on a mix of bravery and greed, the sea captains of the fifteenth, sixteenth, and seventeenth centuries relied on "dead reckoning" to gauge their distance east or west of home port. The captain would throw a log overboard and observe how quickly the ship receded from this temporary guidepost. He noted the crude speedometer reading in his ship's logbook, along with the direction of travel, which he took from the stars or a compass, and the length of time on a particular course, counted with a sandglass or a pocket watch. Factoring in the effects of ocean currents, fickle winds, and errors in judgment, he then determined his longitude. He routinely missed his mark, of course searching in vain for the island where he had hoped to find fresh water, or even the continent that was his destination. Too often, the technique of dead reckoning marked him for a dead man.

[VII] Devine.K Although of course in truth numerics are working away underneath it as it is a digital construct.

Organic Architecture’s colour: draw and project from Fröbel to Steiner

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1. Introduction

Idea, draw, project and colour of organic architecture find their bases in the article of Frank Lloyd Wright “In the Cause of Architecture”, published in the journal Architectural Record in 1908, where the American architect lists the essential points to define the making of organic architecture.
In the organic architecture the theories on the perception and on the application of colour are inextricably linked to the matter, to the nature and principally to human being. The architecture seamlessly blends with nature, capturing the colours and morphology; it’s an architecture of the materials and of the symbiosis, a symbol of the feeling of well being and balance, also due to the choice of colours in complete harmony with the environment through the fusion with building structures. The colour and the light are viewed as an expression of the life of the soul and the colours are bright, as it were transparent in relation to the materials and forms of dynamic spaces designed and built to human scale. This article aims to investigate the relationship between the Fröbel pedagogical approach, the theory of Steiner whose expressionist aesthetic refers to the irregularity of natural forms and their inherent symbolic transcendence, and the implications for chromatic and formal choices of Wright organic architecture connected to the consequent repercussions on the international scene. The interest of this research, beyond the metaphysical conceptions of Fröbel, of his relationships with Pestalozzi and Schelling, wants to detail on the influence of the theories of Fröbel, of his “gifts” and on the ability "to build and to study new geometrical composition with the component parts", crossing the principles of Rudolf Steiner and his conceptions on the living organic architecture, giving a look to the actual relapses.

2. Fröbel Gifts

Friedrich Wilhelm August Fröbel was born in Oberweißbach, in 1782, teacher and pastor, studied crystallography and architecture, and argued that it is in the drawing that the child distinctly shows his creativity. He claimed that the use of geometric solids and of primary colours were a fundamental approach to the understanding and management of forms, their composition and decomposition and location of objects in space.
If for Fröbel every human action is considered creative, the educator will anyway seek to intervene and guide children towards clarity and precision, in order to find “unity” considered by Fröbel the beginning of everything. The games, called “gifts”, were considered “teaching devices”, to simplify the children path towards learning. From the observation and manipulation of different size wood solids, young people will get to derive their common origin from the ball, and then to "foresee" the very

concept of unity. He thinks that learning science should be intuitive. Although spontaneity must be safeguarded and this must be accompanied to the game as an educational tool.
The concept of the unit is reflected in the game when child expressed himself from the inside to the outside and when from the outside, ie from the game, the child makes experiences that become their own, and part of the inside. Through the play of fiction and through the game you find the design that is a form of language that puts the foundation for learning concepts of logical-mathematical, and also for future applications in working experiences.
Already in the first phase of childhood Fröbel highlights that drawing, thanks to the graphic nature, favors the children impulse to structure their internal representations. Game and language are the elements in which the child lives now, so the child attaches to everything ability to live, to feel, to speak and to hear. Just because the child begins to externally represent the inside, a similar activity is also in everything that surrounds him.[1]
We are in the presence of the great discovery by Froebel, namely the centrality of the game promotes the entire development of the child in the direction of the drawing, of the linguistic evolution, of the logical-mathematical, and at the same time prepare for the future work.
Fröbel also fits the movement and physical exercises, rhythm, music, dance. Methodological direction of education in childhood assumes an orientation opposite to that of the previous phase. The exterior, through curiosity and interest, must be internalized (currently learning). The school is, therefore, where man is led out of him and come to the knowledge of the objects according to the special and general laws inherent in them. [1]
The Fröbel theories and the gifts were presented at Centennial Exhibition of Arts, Manufactures and Products of the Soil and Mine in 1876 in Philadelphia where Anne Lloyd Jones, Wright's mother, bought Fröbel toys and forced his son to play with them, in the belief that he would become a great architect. In fact, it is evident from the statements by F.L.Wright as the “gifts” had a great influence in forming the basis of three-dimensional compositions and chromatic forms.

Fig.1 Kindergarten teacher’s workbook , 1890; the seventh gift; F.L.Wright Sketches for windows and Clerestory window from Avery Coonley Playhouse, Riverside, Illinois, 1913.

Wright explains, in a note declaration, that he still feels between his fingers the component parts of the "gifts", highlighting the tactile and sensory aspect implicated in the acquisition phase of the data and how their size is perfectly in relation to the capacity of children to manipulate them and their geometric perfection and tactile quality is what makes them still perfectly contemporary.

Fig.2 Starting with the ball, before metaphysical conception of reality and starting point of all geometries, passes to the multiplicity in the second gift reconciling the two opposing cube and sphere with the cylinder intermediate step. The cube of the third gift consists of 8 cubes whose manipulation leads to awareness of unity and plurality The material is enriched in subsequent gift involving in construction activities divided into three categories that represent the human mind: logical-mathematical forms of geometry, shapes of objects (design and ergonomics) and art forms

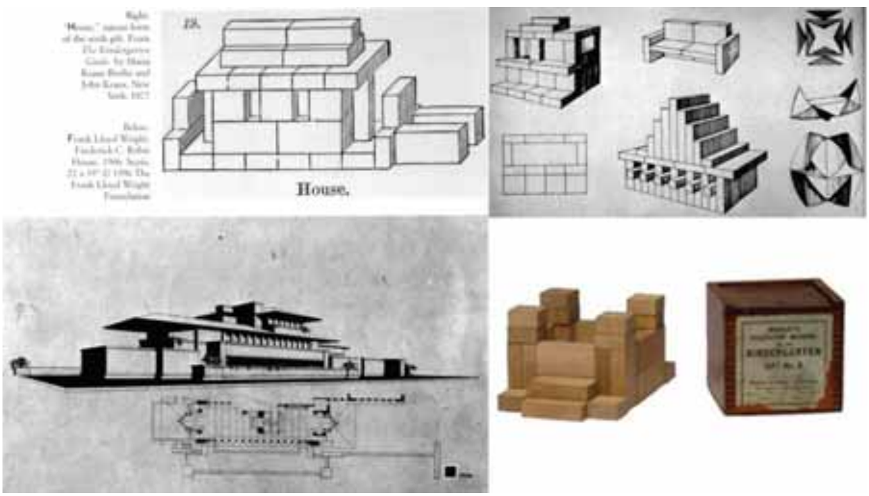

Fig.3 Froebel Gift in connection with Robie House by Frank Lloyd Wright. The sixth gift is constituted by a cube divided into 27 blocks of various sizes. Through this building material children acquire a sense of the relationship between the parts and the whole, passing from simplicity to complexity, through the enrichment of the possible combinations of objects and their manual skills, which, on this basis, it should evolve into creative activities.

Kindergarten Education, as I said, proved an unforeseen source of wealth; primarily because later all my composing pivoted on a suitable modular and proportional system I realized that it would keep everything to its scale, would ensure a harmonious proportionality throughout the building, large or small, which *thus would become - as a tapestry - a fabric consistent interdependent units, and always in relation to one another, as various. Therefore, from the beginning I applied this system of "weaving" in the design of smaller buildings. I found out later that the system offered technological advantages, when it was applied in height. In section, therefore, soon I adopted the form vertical, as experience dictated to me. The plot building - matter - was pretty much the same if you lay on this predetermined scheme. This process proved crucial indispensable; and a good mechanical technique must yield its benefits. It appears invariably, organic architecture, as a characteristic trait visible in the composition, thus ensuring the proportional unit. In this way, the harmony of the weaving is found, together with the scale of all the individual parts of the building, in the effect of the overall whole [2].*

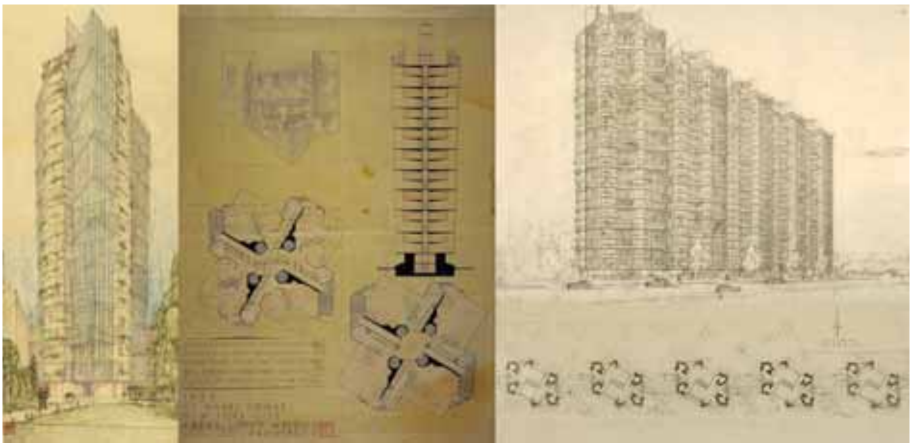

Fig.4 F.L.Wright: St. Mark's-in-the-Bouwerie Tower, New York Project 1927-31; Section and perspective cutaway of a duplex apartment with balcony and living-room floor plans, 1929; Grouped Towers, Chicago Project 1930 Perspective and plan . The Frank Lloyd Wright Foundation Archives (The Museum of Modern Art | Avery Architectural & Fine Arts Library, Columbia University, New York)

In the organic architecture theories on the perception and application of colour are linked inextricably to the matter, to the nature and above all to human being. The architecture blends seamlessly with nature, capturing the colours and morphology, it is an architecture of both the materials of the symbiosis, a symbol of the feeling of well being and harmony due to the choice of colours in complete harmony with the environment through the fusion of building structures. The colour and light in organic are viewed as an expression of the life of the soul and the colours are bright, as it were transparent in relation to the materials and forms of dynamic spaces designed and built to human scale. This is clearly enounced in the article *In the Cause of Architecture* where Wright declares:

IV-Colours require the same conventionalizing process to make them fit to live with that natural forms do; so go to the woods and fields for color schemes. Use the soft, warm, optimistic tones of earths and autumn leaves in preference to the pessimistic blues, purples, or cold greens and grays of the ribbon counter; they are more wholesome and better adapted in most cases to good decoration.

V -Bring out the nature of the materials, let their nature intimately into your scheme. Strip the wood of varnish and let it alone--stain it. Develop the natural texture of the plastering and stain it. Reveal the nature of the wood, plaster, brick, or stone in your designs, they are all by nature friendly and beautiful. No treatment can be really a matter of fine art when these natural characteristics are, or their nature is, outraged or neglected. [3] (In the Cause of Architecture, March 1908, Architectural Record)

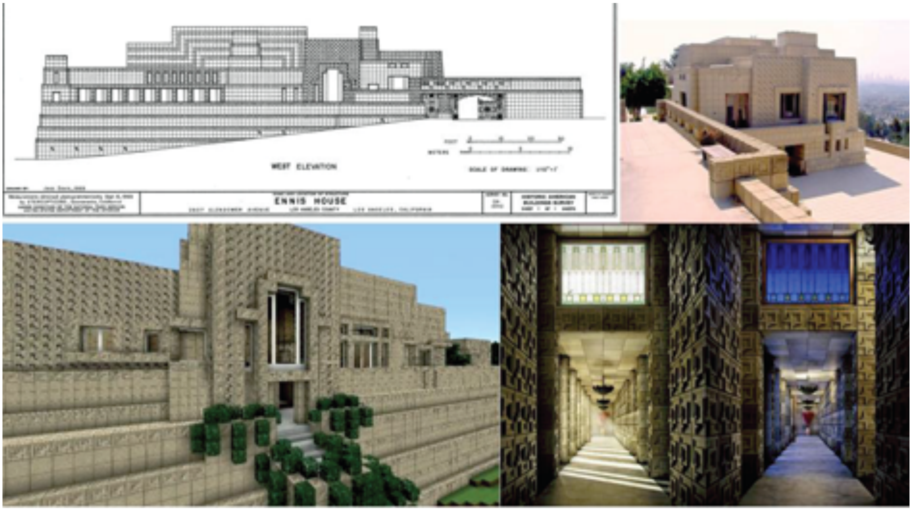

Fig.5 F.L.Wright, Ennis House 1923. Following *La Miniatura* in Pasadena, and the Storer and Freeman Houses in the Hollywood Hills of Los Angeles, the structure is the fourth and largest of Wright's textile block designs. Light and colour effects by day and by night. The "textile-block" System by Frank Lloyd Wright transformed a building material element in the economic construction of high accuracy and high level aesthetic. The use of rectangular blocks of concrete standardized, prefabricated and decorated with the aid of wooden matrices for the first time determined a geometric pattern defined by the same blocks of 16x16x3-1 / 2 inches lasted up to 50s.

3. The Antroposophy influence colour-light: the geometry of the shape

The organic living architecture is inspired, more or less directly, by Rudolf Steiner (1861-1925), the founder of the current of Anthroposophy that materialized in its most representative architectural work: the Goetheanum and the smaller buildings in the town of Dornach, Switzerland. The architecture, according to Steiner, is the outward visible image of the multiple nature of human being, and consists of a complex totality evolving into a complex and dynamic triad of body, soul and spirit as a mediator of this experience , because this relationship between these opposite dimensions of spirit and matter, the soul is the nature of man.
A definition that Rudolf Steiner did about architecture summarizes very clearly this fact: "The architecture, the art of building is to project outside the inner space, the laws system of the human body" (conference of 29.12.1914). These principles are inextricably linked to Steiner Pedagogy: from movement to geometry.

Steiner was one of the most influential educational theorist of the twentieth century, he illustrated his lectures trough sketches on black paper or blackboard communicating his sense of creative energy, introducing the principles of Antroposophy where the individual is part of a larger metaphysycal harmony.
His first School was for the children of employees at the Waldorf –Astoria cigarette factory in Stuttgart. His method was such successfull that Steiner Schools were estabilished in many european countries and in the United States .
The principles of the thought of Steiner are spread primarily through pedagogy, it is like starting with a blank slate on which to write the future, that's why Fröbel and Steiner are such important figures, because the thought applied to pedagogy touches all the moments of growth , that a child acquires and will develop as an adult. Before using colour as a property of objects and before knowing the laws of colour in physics, the child is guided through the experience of various colours, of their individual character and of their relationships.
The child can feel through colour what colours can tell him, because in them there is a whole world. But it also gives you a way to live what the various colors have to say to each other, what does the green to red, blue to yellow, blue and red to green to blue and so on. This way you do not explain to child abstract symbols or allegories, but you do everything with art. Then ensure that the child, in the wake of the artistic experience, will form images on paper, will have fun to pop out the letters starting from the figures, just as men did over millennia starting from a writing in images. (Rudolf Steiner, Art of Education Art of Living)
Similarly, you should experience the "gesture" of straight lines and curves through movement in space and freehand drawing before using those lines to write letters and numbers, and long before of relating them to each other with geometric laws. To exercise beautiful lines, beautiful curves, beautiful corners you will lead to develop a feeling for form, learning to be aware of the page as a whole to develop a sense for space and movement.
The line divides the space, and its location in space is connected to the sense of balance. Drawing forms develops the intellect and the design of sequences, i.e. forms that gradually change into others, develop in children flexibility of thought and understanding the idea that the world around him is constantly changing.
To experience the vertical is both an Ego that expresses the soul qualities of thought. The curve is connected to the world around him: looking around we slips over things in an arc. In this gesture the children can feel the forces of the Will beginning to perceive the opposite qualities of the forms in which the polarity of the human soul is reflected.
The shape comes from the movement that precedes the drawing itself. Also forms consist of rhythmically repeated lines have many aspects: careful drawing of the lines, following the whole movement but stopping at the right time, to adjust the space between lines, changing their length, the perception of space page, acquires an "alphabet shapes" made up of individual characteristic elements. The next step are the exercises of symmetry that must complete half of the form with their feelings and their imagination. This implies a conscious tension and an activation and interplay of the senses in order to get not only the same shape but also the very fullness of the side, and then the "double symmetries" where the line crosses the

axis, to exercise the full range of central symmetries with three, four, five, etc. symmetry axes.
In the forms are practiced rhythmically repeated large variety of corners and intersections to combine two or more simple movements that have the same rhythm. Drawing forms is presented as freehand geometric shapes through comparison between the forms. Similar to what happens in zoology and botany, where there is an order to the variety of natural forms, in geometry through comparative observation you can create a first order among the simplest geometrical shapes: the circle and the straight line in relation to it (secant, tangent, radius), the similarities and differences between the various forms of quadrilaterals and triangles.
This process of "observation and thinking" is the attitude behind every scientific thought. The natural result of the design of forms is the ability to deal with imagination and sensitivity the most challenging tasks set like painting, sculpture and architectural design as well as at the highest level, making spring from that sense of movement of thought and imagination, the delivery capacity to realize what the design of forms in metamorphosis has already been able to anticipate.
The thought by R. Steiner influenced across all disciplines of contemporary culture, inspiring the work of artists like Piet Mondrian, W. Kandinsky and F.L. Wright.

Fig.6 R. Steiner, Sketches on the blackboard on the theory of colours; study of colour and shapes by Vasilij Vasil'evič Kandinskij (Circles in circles, and Some circles Museum, New York1926); R.Steiner, The sketch of the second Goetheanum on the blackboard and its geometry; F.L.Wright, Taliesin West Armchair.

The "drawings on the blackboard" (Wandtafelzeichnungen, coloured chalk on black paper) by Rudolf Steiner, about 1100 made during the lectures in Dornach (Switzerland) between 1919 and 1924, explain his theories on science, philosophy, politics, medicine, art, architecture and agriculture. The "drawings on the blackboard" in the intention of Rudolf Steiner don't born as "works of art" but as signs of thought ("Denkzeichen).

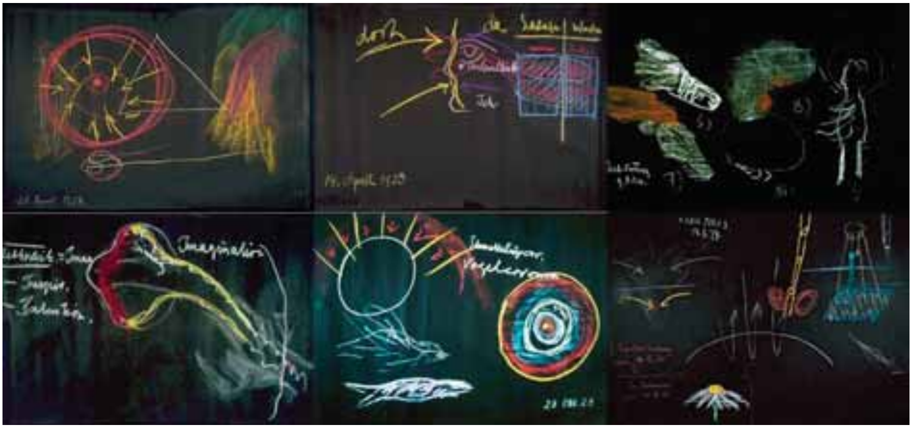

Fig.7 The thematics of the conference expressed through the sketches become concrete idealism, practical philosophy. Steiner dealing with knowledge and social life turned to philosophical and scientific thought to overturn the aesthetic categories of beauty and the idea to "see science through the the artist and art connected life ". These principles are the basis of living organic architecture by Rudolf Steiner, even today current.

Rudolf Steiner argues that the relationship between man and architecture, is a real connection of an organic-dynamic character, similar to the metamorphosis and transformation of human growth such as transformations and growth of man reflected in the architecture and more specifically in its quality of light, shadow, colour, chromatic surfaces and volumes, but also in particular architectural design language. The approach to colour in living organic architecture sees as basic reference the experience that man does in relation to the environment colourful nature (rainbow colours of animals, flowers and vegetation ... change of colour perception during hours of the days and seasons and climate change), so the decision to paint an object or an architecture is an action soul, that soul is perceived and interpreted by the architecture.
With colour, you build an architectural and urban landscape that communicates and collaborates with the man. Steiner has dedicated 12 conferences to colour organized in three parts: Part I: The Nature of Colour Lecture 1: Colour-Experience (Erlebnis) , May 06, 1921; Lecture 2: The Luminous and Pictorial Nature of Colours, May 07, 1921; Lecture 3: The Phenomenon of Colour in Material Nature, May 08, 1921; Part II: Colour in Light and Darkness; Dimension, Number, Weight - Lecture 1: Thought and Will as Light and Darkness, December 05, 1920; Lecture 2: The Connection of the Natural with the Moral-Psychical. Living in Light and Weight.December 10, 1920; Lecture 3: Dimension, Number and Weight, July 29, 1923. Part III: The Creative World of Colour - Lecture 1: The Creative World of Colour ,July 26, 1914; Lecture 2: Artistic and Moral Experience ,January 01, 1915; Lecture 3: Colours as Revelations of the Psychic in the World ,May 18, 1923;Lecture 4: The Hierarchies and the Nature of the Rainbow ,January 04, 1924.
Steiner emphasizes, through his lectures represented on blackboards, colored drawings and diagrams the relationship between man and architecture as the basis of the anthroposophic spirit (human physical body - materials and building structure, vital body - form and massing, soul body (astral) - light and colour; language; stylistic body ego - space; identity function)

The size of the two domes of the First Goetheanum, the spatial definition of the second Goetheanum and external balance of relations between space, volumes of the buildings of the complex of Dornach is in relation to the surrounding landscape.[4]

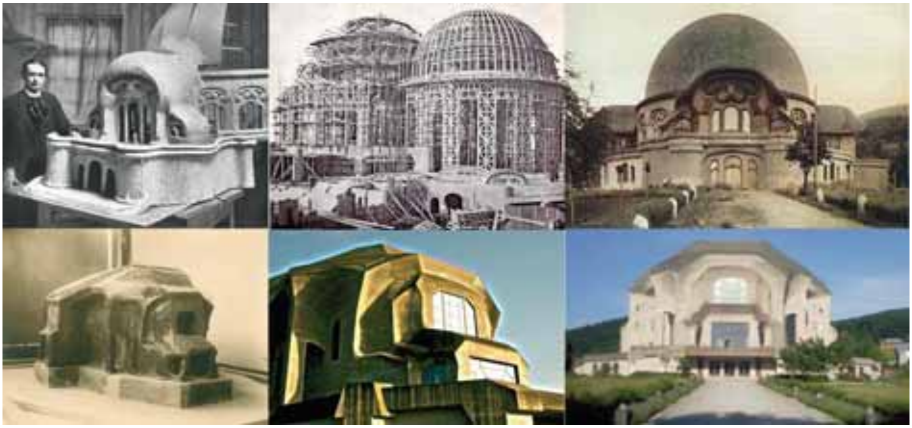

Fig.8 R.Steiner near the First Goetheanum Model , 1914. the wooden structure under construction, the great dome of the first Goetheanum ; the second Goetheanum: plasticine model made by Steiner in 1924, (photo Otto Rietmann, Rudolf Steiner Archiv) ; the Second Goetheanum in concrete.

The space in living organic architecture is a tool for man to understand himself in the relationship with the outside world. The irregular shapes evoke natural and spontaneous forms of the earth , of the rocks and of the symbolic transcendence.
The extraordinary aspect of this vision is that despite being strictly scientific and abstract, has a direct practical reflection. Since that time Rudolf Steiner undertakes to submit works in the practical consequences of the new coherent conception called Anthroposophy.
The architecture, seems perfect to realize these theories, and from 1907 Steiner designs preliminary works that will find the maximum consistent with theories anthroposophic in size of the two domes of the First Goetheanum in Dornach (1913-1922), built largely in wood and then destroyed by fire, and the spatial definition of the second Goetheanum built this time completely concrete, is a reminiscent of Hindu temples carved into the rock, this is the reason of external balance of relations between space, volumes of the buildings of the complex of Dornach in relation to the surrounding landscape .
The choice of concrete comes from the fact that the author felt the need to be able to mold the clay forms as they were, in fact, the plasticine model developed by Steiner wanted to make the idea of the perfect integration with the environment, although seemingly so different from that of 1913, the new building combines the theories of Steiner related to the revival and the return of natural forms, just like the houses dug into the rocks.

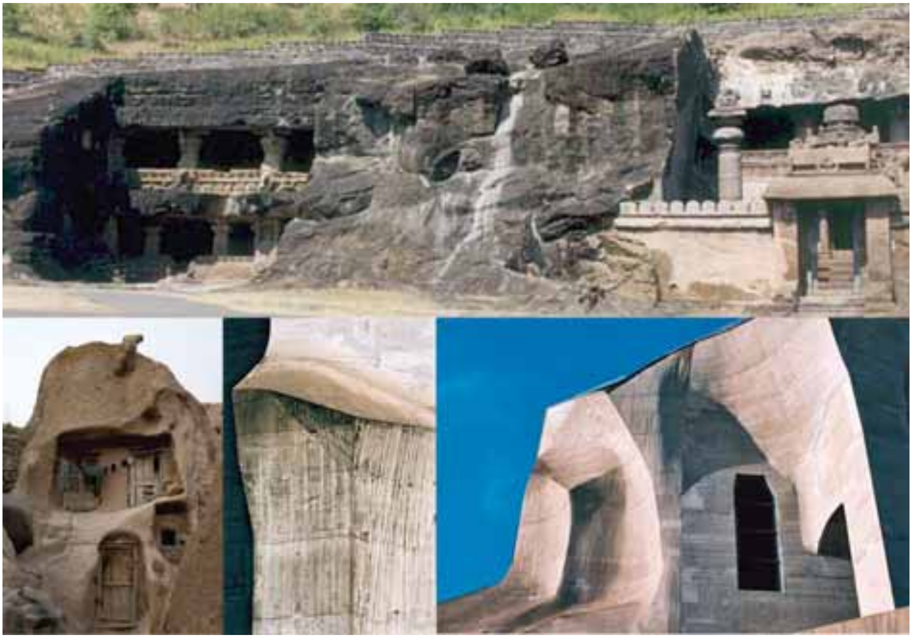

Fig.9 Ellora Caves in India Maharashtra; House dug in the cave, Iran; Details of the mighty concrete forms of the second Goetheanum (Photo by Christiaan Stuten). Concrete is a material that can be can behaved like wood in construction tectonic "pillar and beam", but it can also slide in roles agile, a-tectonic, like clay.

The characteristics of Steiner Architecture are very complex and difficult to describe, however, simplifying, in them can be found, as well as much more, the traces of the fourfold articulation mentioned above. Faced with what organic architecture living opposes a formal quality of buildings that not only is rich and varied, but ever changing dynamic course in the artistic dimension of imagination.

In the Steiner architectures plastic sculptural quality of shapes , volumes , of the decorations are complex , multifaceted and they express essentially the external quality fundamental of the living world : the metamorphosis of forms . The space is configured as a dynamic balance between movement and stillness .

We find ourselves immersed in a total project where architecture, literature, philosophy, images , decorative arts , design , study of colour and alchemy geometry combine to represent a world of psychophysical elevation.

Fig.10 Interior views of the Second Goetheanum, where are applied colour theories of Steiner, infact red is indicated for passage areas, corridors, while purper is used to create a dignified environment: entrance of hospitals, places of worship and meditation, but also for celebrations and conference rooms.

4. Conclusions

Topics covered in this article can not be said exhausted because of the principle inherent the analyzed theories. There will always be some new architect, artist, educator, scholar, which addressing these issues will not resist to investigate them and to structure new ideological links to organic architecture, to the educational principles of unity, to the colours as an expression of a soul path or to find in some unusual architecture all the principles that work, the return to "natural", architecture and colour ,the link to the Hindu temples carved into the lava with houses carved into the ground in Iran or in Italy to the Stones of Matera.

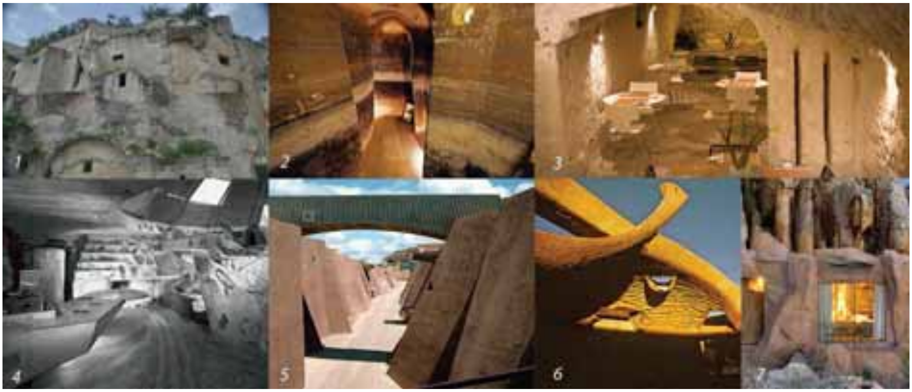

Fig. 11 : 1 Stones in Matera, 2 Stones in Matera, water collection, the cistern, 3 Stones in Matera, interior, reuse, 4 P.Soleri Dome House, 1949, Cave Creek, Arizona interiors , 5-6 P.Soleri, Amphitheater 1970, New Mexico: Entrance runway was dug and the earth sculpted to provide a rigid body upon which a thin shell of concrete was poured., Amphitheater, 7 Resort with rooms dug in the cave in South Africa.

Beyond the historical contingencies of human and climatic conditions that led naturally to these accomplishments, Paolo Soleri (1919-2013) strongly wanted to propose some principles, sometimes exasperating, refusing, in contrast with his friend Wright, the machine , and trying the union with the earth and the spirit, designing houses and cities in the almost worrying spirit of isolation.
In P. Soleri Dome House coexists the two principles: the house is of the earth, but at the same time, thanks to the dome, is over. Paolo Soleri will tackle this in his project of Arcology "ecology" and "architecture”, experiencing other fascinating solutions, but ever so elegantly and resolutely synthetic such as the project of the city of Arcosanti. The officially describtion of Arcosanti in Arizona is:" The built and the living interact as organs would in a highly evolved being. Many systems work together, with efficient circulation of people and resources, multi-use buildings, and solar orientation for lighting, heating and cooling. "The city was founded by an informal and no geometrical spirit. For the apparent primitivism, to vibrate matter , for the choice of simple solutions that belong to the earth.

Fig. 12 P.Soleri, Arcosanti City, Arizona , 1965: draws, views and details.

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Design of colored furniture for green spaces to protect the privacy of users

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1. Introduction

Cultural design is one of the new approaches in design to consider the social and cultural rights of a population living in a space. In the field of furniture design, this approach is directly in relation with citizens to recognize their needs and highlights the cultural codes particularly which bring a type of message among them. Each society has its own cultural codes that must be discovered to apply in a product, service or space design. For example in some countries, using the green spaces to celebrate a traditional memory day is not so frequent but in another countries, the population prefer to spend this moment together on the ground or sitting on the furniture placed over there. Iran is a country with relatively high cultural level points. Certain points are highly visible even in the country's image when you walk on the streets or you participate in a ceremony etc. The issue of private and public is something that is directly related to the country's culture and even the culture of different regions. The ancient architecture of this country also emphasizes that respect for the people to put them in some kind of protection. This protection is sometimes from climate and its changes during the year and sometimes from the vision of others. Most of old Iranian houses have an entry space that allows inhabitants of the house to prepare before the person come in the house. This space called 'Hashti' is a symbol of protection in Iranian architecture. This space is sometimes transformed in the form of 'Dalan' which is longer and has the same function between the point of entry of the house and the interior space. Urban furniture can also play an important role in defining the boundaries between public and private. When someone sits on a bench, he/she creates naturally an invisible space around him/her and the other people can understand if they can sit near him/her or not. These types of message can be transmitted by some design elements which facilitate to understand some cultural complexities. For example if people participate in the arrangement of furniture in green spaces and change them according to their needs, it is easy to see that the space is already occupied for a particular activity. This understanding of the social situations permits everyone to respect others while enjoying their activity and creates a new form of communication with others.

This study was undertaken to investigate the Kansei method and characteristics of cultural design, in particular for the green spaces in Shiraz, one of the famous cities in Iran. The concept of privacy in furniture is sometimes more complicated that we can imagine; and for this reason this study carried out to understand its meaning in particular among regional people. In the first part of this research we establish the theoritical analysis of environment, users and furniture based in the green spaces.

The second part concerns the design parameters which are essential to create an accordable furniture for green spaces protecting the privacy of users. Inspired by some childhood games, the colored furniture proposed in this study uses an original combination of color and motion to create a harmonious space in the city. Incorporating Kansei model into this research suggests the characteristics and required parameters which were collected through observation and deep interviews among Iranian families residing in Shiraz. In-depth interviews were conducted with 45 participants in order to collect responses that showed the evidence of good feelings with colored and private furniture. This article then explores the role of colored furniture in green spaces and its interaction with users. Finally, this paper presents a unique colored furniture design model to provide an interface which communicates the commodity and privacy as well as an aesthetic and emotional experience to user. The study focuses on the user's analysis and the sensorial properties of materials and mechanisms influencing the human activity in the public space. In the detailed design, some features such as safety, environmental impact and manufacturing process are considered.

2. Theoritical Analysis

The role of urban furniture is so important and decisive to serve the users of the local areas. The cultural messages can be transmitted by an appropriate urban furniture. Not only the cultural messages but also the social and political constraints may be used in a public element. The capacity of design in this area enforces people to interact with the elements around them and give them the power of analyzing their environment including some standards and spatial conditions. Understanding these standards and spatial conditions requires careful studies on the regional culture and what users demand from any kind of urban furniture. This study attempts to study the possibilities and limitations of furniture for green spaces. So the strengths and weaknesses of current furniture equipment from the point of view of users are recognized in the field study. Giving the range of hypothesis addressed to the historical context of the city (Shiraz) and its culture on one hand, and the concept of privacy on the other hand, the study provides the appropriate conditions to formulate the initial ideas.

2.1. Environmental Analysis

Urban furniture is a set of facilities that enhance the quality of citizens life in efficiency in the public espace with a tight relationaship between its cultural and historical origine. Any location has its own originality to be inspired in furniture design. Streets, alleys, parks, etc. can reflect the characteristics of cultural identity of each location which impact on the life of public urban space. In this research the case study is the city of Shiraz which is known as the centre of Fars province. This city is located at 900 km from Tehran and has an altitude of about 1490-1700 meters from sea level. The lowest point of Shiraz is located on the south-east of Maharlou lake and the highest point is located in the northern plains. The average temperature of this city is about 15° during the year[1]. The population of this city in the last national report is over than 1, 455,073 [2].

Shiraz is one of the cultural cities in Iran with a long history in persian traditions such as privacy boundaries in architectural constructions. This cultural expression is visible in differents manifestations which require a clear definition of public and private such as urban transportation, some entries of public et religious espaces etc.

2.2. Human and Privacy

Some environmental factors such as temperature, softness, hardness, depth and light influence the understanding of the environment. These factors depends also on the personality and understanding level of individuals and they are not far from the cultural background. The factors relevant to the understanding of the environment and personality are as folows:

- Personal factors such as experience, gender, age, education.
- Cultural factors and the environment.
- Physical factors [3].

The built environments are in order to make some traditional societies more disciplinaire and sometimes this activity is a holy vison of the world [4]. Privacy for each human being concerns his/her environment and space which is not accessible to the others. This space must be protected visually and other audio sensory stimuli should not enter without individual's permission. Sometimes this concept comes with the terms like quiet privacy or confidentiality which can be mixed and at the same time, they are in the opposite of the terms like crowd [5]. Private spaces and their relationship to the built environment in the private sphere create some global congestion to the population caused by crowded spaces. People are frequently in exposure to the excessive stress among individuals. In this context, Designers, with the aid of knowledge of concepts, can contribute to the practical realization of the built environment more creatively [6].

The concept of privacy can be divided into four categories:

1. Privacy depends on relation.
2. Privacy is closely related to our sense of control or autonomy.
3. Privacy is important to our sense of identity.
4. Privacy lets us release our emotions [7].

Hall in "The hidden dimension" uses the terms of the flight distance, the critical distance, the personal distance and the social distance for "every human being".

The personal and social distance are more objectives and they can be identified in four groupes (Fig.1.):

1. The close distance (45 cm from body) to create a very close and personal opportunity to touch and feel the heat in the gap between the two sides.
2. The environmental or protective bubble: the range between 45 and 120 cm around body. There are two kinds of this distance :
   (A) Close personal distance mode: In this distance a person can keep other people or not.
   (B) The personal distance away: keeping one arm's length away.
3. The social distance (from 120 to 360 cm) for non-private (temporary labor relations).
4. The general range (above 360 cm) by monitoring the interaction between people and preventing undesirable behavior [8].

Fig. 1 – Personal Distance

In order to protect the privacy of Iranian traditional architecture, the entry of spaces are built in such a way that people can not arrive directly in the interior part of the home. There are some elements like gates, two platforms to sit on waiting entrance or a long Dalan and Hashti. These elements decrease the visibility of interior. Another example of such architecture is the entrance to the citadel of Karimkhani illustrated in Fig.2 [9].

Fig. 2 – Entrance to the citadel of Karimkhani in Shiraz

Philosophically the concept of privacy has two main topics, the first is related to the privacy of individuals and the second is related to the amount of the applicable privacy boundaries. Both of these approaches have a definition of privacy as benefit or legal right for everyone which must be supported by society and law. Many theorists believe that privacy is a concept in itself which is valuable and meaningful[10]. Sometimes there is another kind of private espace which accept people without inviting them to enter and create a general station of privacy [11]. In iranian culture each space has its own requirments. Generally in term of their application, these spaces are divided in three categories of private, public and semi-private or semi-public. In another definition "urban space is the space that everyone goes through from the home to the work during the day" [12].

2.3. Urban Furniture

Furniture is a french word which means furnishing or decorating a place. Urban frutniture is a wide range of equipement, supplies, devices, elements and symbols which are installed in public spaces [13]. Urban green space furniture (benches, lighting, trash, etc.) is a dynamic form of installation which enforces the soul of nature in the city. The emergence of urban green space furniture and its history is interwoven with the birth of the first cities.

2.3.1. Enclosed Furniture

Enclosed furniture provides some kinds of privacy to a person or persons. In terms of the performance, it can be devided in two types:
1. *Flexible:* This type of enclosed furniture can be confined to a non-enclosed furniture (Fig.3. at left).
2. *Unchangeable:* This furniture has a larger volume and it is unchangeable (Fig.3 at center).
3. *Combined furniture:* This type of furniture is a combination between private and public (Fig.3. at right).

Fig. 3 – Enclosed furniture types from left to right : Flexible, Unchangeable and Combined.

3. Study methodology

Kansei engineering technique is a design research methodology proposed by Professor Mitsuo Nagamachi in 1970. This method concerns the ability of measuring the various emotions and their relationship to actual production characteristics. The aim of this design thinking is to deliver the products which affect the human emotions. It is also a helpful tool that encourage people to use their life equipements with another vision in order to meet their cultural and social needs [14].
After determining the user requirements and translate them into keywords with a meaningful classification, we can obtain some information on product characteristics such as form, color, and the other details which are essentials to product developement [15].
To find the design parameters of furniture for green spaces, the Freedom Park which is one of the famous green spaces in Shiraz is chosen. In order to answer the questions based on project planning and furniture design with an approach to privacy, all of the interviews and field study is taken place in this park. The situation of this park is shown in Fig.4. The target group has a range of 5 to 75 years old.

Fig. 4 – Plan of the city of Shiraz and the location of Freedom Park.

According to the Kansei engineering method, there are three steps to develop the structure of product : Kanei keywords gathering, Structuring Kansei keywords, Evaluating Kansei keywords. The first important collection of keywords contains from 50 to 600 words. These keywords are extracted from 10 existing products in the field of furniture design proposed to 45 users in many process of interviews. The sum of all the 101 words is established to create the basic structure of furniture. These keywords are decreased to 51 chosen words. In this step for each category of words, one representative word is proposed to cover them. The users determine thus the words such as comfort, fun, green, warm, charming and attractive according to their value. In the next step, it must formulate the product parameters depending to the degree of importance of the selected words. Finally, these parameters represent the final furniture.

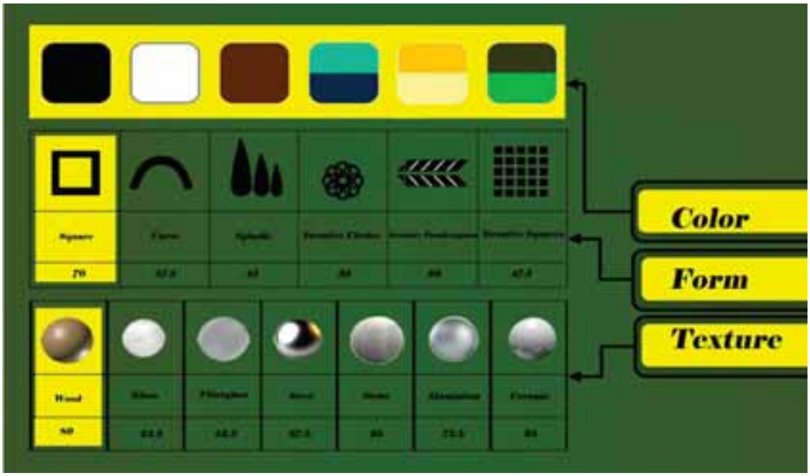


Fig. 5 – The combination of color, form and texture in the furniture elements situated in Shiraz.

At the first step, the principle parameters such as form, color and texture are considered by comparing the gathered information. The results obtained in the field of color illustrate that a range of colors including blue cobalt, turquoise, green, purple, brown dark, cream and gray define the principle colors represented the image of city for users. These colors with a combination of persian patterns are suggested such as the spindle side, the lotus flower (repeated circles), square, trapezoid and iterative empty curve. Most of these forms are shaped like a clear and recurring motif for users. The current materials used in the urban furniture in Shiraz are cement and armed metal combined with a range of bright and dark green, red, white, cream and black colors in the rectangular form.
The design approach in this project concernes the concept of privacy of users that demand the physical conditions of furniture in green spaces. These conditions define some categories of current furniture (more than 100 models) for analysing including security, comfort and privacy. The users define the selected models by a word including introverted, organic, flat, collective and modular.

From this study it can be concluded that *Introverted furniture* includes the words of safe, warm and pleasant; *Organic furniture* is accompagnied with attractive, pleasant and green, *Flat furniture* represents pleasant; *Collective furniture* contains attractive, warm, pleasant; and finally *Modular furniture* is representative with charming, funny and sincere. Finally, according to the results, the introverted and collective furniture are selected by users.
In this way some materials such as wood and aluminum combined to the form of square, curved and the colors like turquoise, green, brown, yellow or white are suitable for this type of furniture in the opinion of users.

4. Results

The process of conceptualization and modelization of ideas has been developed around the selected categories of concepts considering the privacy of users. Each idea is evaluated with the respect to performance and its degree of privacy in a green space. Finally three concepts of station, butterfly and cube are selected to be developed in details. The idea of CuBe has become the most efficient and interactive idea between others. This idea is modified by value engineering process to be prepared to the final step of realization (Fig. 6).

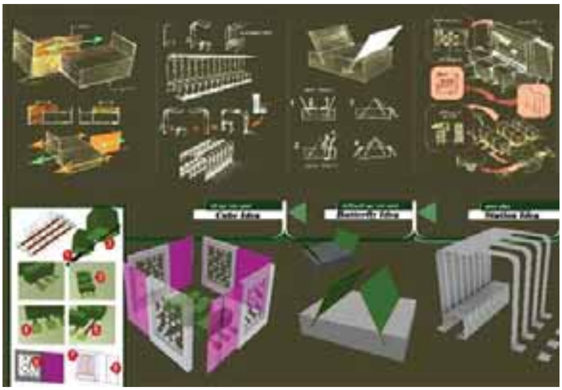


Fig. 6 – Final ideas and sketches

Value Engineering Process is a systematic approach, based on creativity and teamworking to solve the problems, reduce the costs and improve the performance and quality of projects, products and processes. According to the International Institute of Project Management, Value Engineering creative approach to optimize life cycle and costs, save time, increase profits, improve quality and solve problems for an optimal use of resources. This approach help us to propose not only the materials but also the suitable process of manufacturing in term of price, quality and physical charactersitcs in differents conditions.
The interaction scenario of users with CuBe furniture is presented in Fig.7. according to this scenario there are five steps of interaction during this process:

1. Users enter in the space and change the position of CuBes only in the direction of cables fixed on the ground.
2. Defining the composition of CuBes for individual or collective use.
3. Moving CuBes to create a group of chair and table.

4. Moving CuBes to create a long bench.
5. Moving small CuBes on the wall to create a personal pattern or message. Each CuBe has four possibilities to select the favorite color.

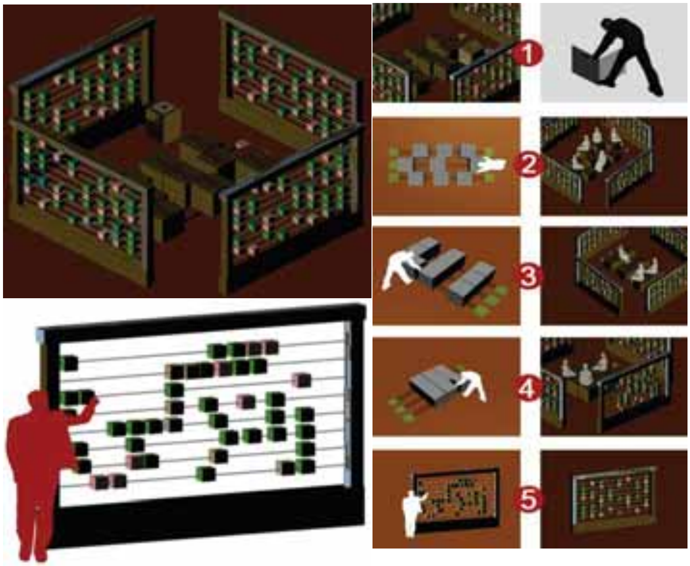


Fig. 7 – Interaction scenario of CuBe

The environmental graphic is considered in this project as an important tool to create an affective furniture in green spaces. Using color in interior and exterior of this furniture plays a key role to give a dynamic aspect to it. The small CuBes situated on the exterior part of this furniture have a range of colors selected by users (Fig. 8). On the central CuBes in interior of furniture an artistic approach is used to create an iranian ambiance. This technique is a kind of graffiti on the wood using ancien pattern inspired by traditional sport in Iran. This artistic technique has some advantages such as : reduce the vandalism effect from users because these patterns can not be cleaned by them; the pattern can be changed by artistes according to context; using WPC and the powerful effect of color on it.

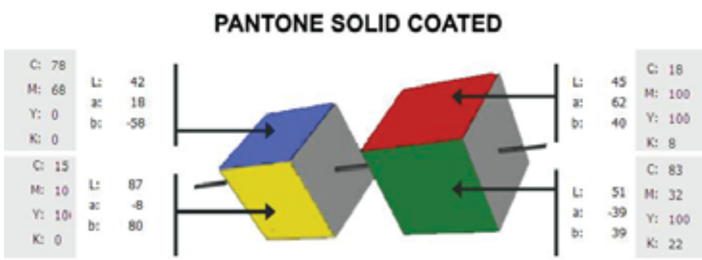


Fig. 8 – The color of small CuBes on the wall

Fig. 9 – Using colorful graffiti on the WPC

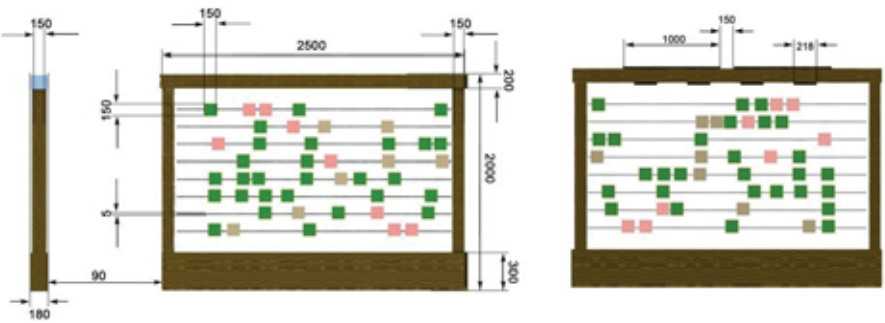
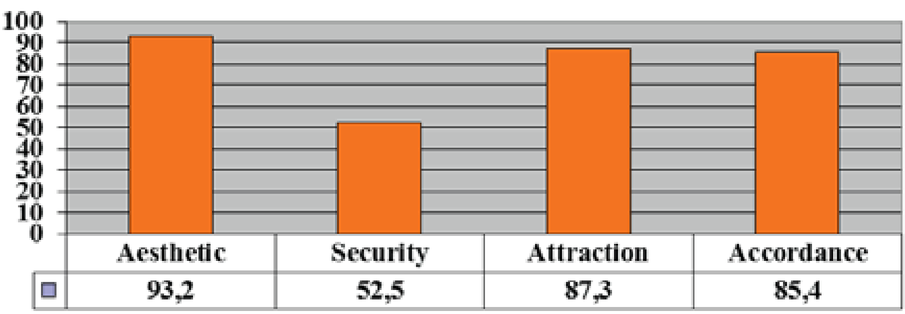
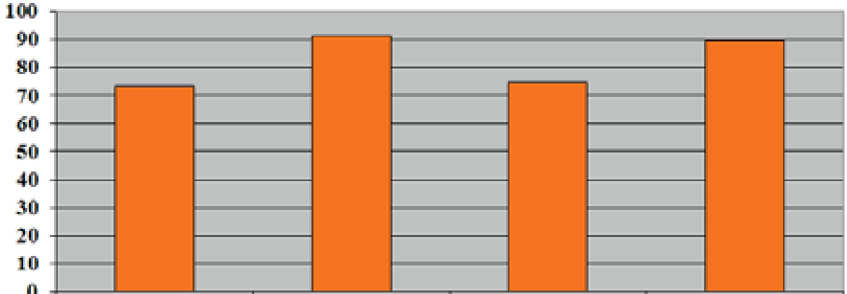


Fig. 10 – Technical plan

The final concept is presented to users and they evaluate it from their point of view. All the users suggest the graphic aspect of furniture and the color used in it as a powerful element in this product. The subject and the colors are the key element to define the context of using this furniture. These results are presented in Tab. 1 and Tab 2. which concerne the exterior graphic of product and the graphic using in interior of furniture.



Tab. 1 – User's opinion on internal graphic of furniture



	Aesthetic	Security	Pleasant	Enlivening
■	73,23	91,2	74,5	89,5

Tab. 2 – User's opinion on external graphic of furniture

Fig. 11- Lighting furniture to create another ambiance at the night

6. Conclusion

The objective of this study was to develop a clear and well-defined furniture to obtain an intimate space reflecting cultural elements of Shiraz which could be installed in a green space. A view on the green spaces of Shiraz makes the subjective perceived character of the city for convivial togetherness and privacy associated to sociability. Colorful furniture is generally associated to positive interest and surprise but also to a negative perception, due to disturbance and lack of identity and meaning in relation to the city. Insights from the research suggest that urban furniture design should be focused on quality instead of quantity and should not be defined in a rigid structure and color but rather it should provide an interactive framework of different color and lighting stimuli for an overall, designed, visual, tactile, and emotional furniture. Social-oriented furniture should assure a warm and comfortable ambient with a good sense of privacy to create a restful and reassuring space for people. Dynamic furniture can provide different possibilities for excitement and points of interest within the space. It means that this type of furniture creates a charming atmosphere, more than this, it can be adaptable to social activities and patterns of use of the green spaces for growing environmental demand. The atmosphere is mainly defined by private logics and choices both in terms of furniture composition and creating a positive and more rich visual environment for people's purpose. From functionality and safety perception, furniture for people is asking for enhancing their experience. Meanings offered by furniture are generally easy to understand but with the effect of provoking the eye without other stronger contribution it can encourage participation, physically engage the occupants of the space or inform for a better privacy. This furniture is not only for the green space but also for a meaningful use of furniture for people to create a social determined urban furniture. The effect of the manipulation of color and light provides different possibilities of exploration of the space. The methodology proposed in this paper can be surely improved and needs more information on existing urban furniture in green spaces in the other cities. However it represents the first step towards a furniture design that respects materials, architecture, chromaticity and privacy of urban spaces.

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The Colour is served! Synesthesia of the taste and room in Futuristic Cuisine

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Abstract

Food arouses a sensory synesthesia. This stimulated the fantasy of Futurists, they chased the convergence of formal arts, indeed. The cuisine could be a scope of global art, because the enjoyment of food involved five senses. Recipes are a demonstration of their experimentation with tastes, smells, sounds, tactile experiences and colours as well. They suggested provocatively food combinations that were unpublished and unlikely to stimulate the enjoyment of all the senses but taste. The formulation emphasizes the role of artists in the birth of a new vision of the alimentation, in which formal and chromatic aspects take over as interactive elements with the sight and the touch. The paper aims to investigate the role of colour in the synesthesia of the futurist cuisine that involved as much food as the rooms, documenting the importance of the futurist heritage on contemporary cuisine.

Key words: Futuristic cuisine, color synesthesia, food design

1. Food as a global art

The Futurism was the avant-garde movement that more than others pursued the convergence of all arts through a radical experimentation. That involved formal arts as well as many aspects of daily life with the declared aim of provoking the renovation of social usage. The aesthetic value resulted in the search for a synthesis of the five senses.
Perhaps nothing else satisfies the animal sensitivity as food: in eating the sight and the smell anticipate and reassure about the tactile stimulation of taste in the consumption of the meal. Many idiomatic sentences, as well as the care in food preparation highlight our instinctive tendency to eat before with our eyes and than with mouth.
The Futurists therefore couldn't neglect food, which once exceeded the needs associated with the fulfilment of appetite, had already evolved as the "art of the taste". Food could become a scope of global art.
Marinetti couldn't pass up this wonderful opportunity and in 1909 he affirmed "*the importance of nutrition on the creative, fecondative and aggressive capacity of breeds*", arguing that "*We think, we dream and we act according to what we drink and we eat up*". The cuisine could be a great testing ground for new, unusual combinations of flavours, smells, colours and shapes to produce multi-sensory stimuli, meaning gustatory, olfactory, visual, tactile, not to mention hearing.
The very experimental approach will be developed only twenty years later, long after that the first Futuristic cook Jules (Jarro) Maincave joined the

movement in 1913, while Apollinaire formulated the Cubist culinary theory[1] and Carlo Carrà wrote the *Manifesto of painting, sounds, noises and smells*.

Fig. 1 – Color and innovation on the Futuristic table: Djulgeroff's menus for the Taverna del Santopalato, advertising and cocktails (polibibita) by Depero,

[1] Apollinaire, *Le cubisme culinarie* (1913)

The following year, the French chef published an article in the form of interview, named *The Futurist cuisine*.[2] He presented it as an original search of harmony of the setting of the table with the colours and flavours of the food. He complained about the boredom of traditional flavours, suggesting new combinations of merely rupture, which anticipated by decades the proposals of nouvelle cuisine, and a more modern setting of table without any other sensory relationship.
The real test, however, followed the first publication of the Marinetti's *Manifesto of the Futurist Cuisine*[3] and the subsequent promotion of a research that recognized food as a formal expression of ingredients, capable of stimulating the enjoyment of all senses.
The following year, Sonzogno published the book *Manifesto of Futurist cuisine* by Marinetti and Fillia (Luigi Colombo). Authors preached the elimination of pasta, which weighed Italians' mind,[4] the abolition of cutlery, not to spoil the tactile pleasure of the body, and the traditional condiments as well as politics at the dinner table. They invited chemists to invent new "*simultaneous and changing mouthfuls*" flavours that could be accompanied by music, poetry and perfumes.
Menus and recipes, which they call "formulas", completed the Manifesto. They emphasized the role of artists in the birth of a new vision of food, in which formal aspects of shape and colour interact with the sight and the touch.
The futuristic cuisine is therefore a transversal and "interdisciplinary" art. It involves all aspects of food, starting from the somewhat 'contradictory involvement of doctors, called to prove the nutritional value of new proposals, and chemicals, invited to create a synthetic food to feed human body with pills, artificial protein compounds, synthetic fats and vitamins. That was the final goal of the futuristic cuisine! The substitute for real food would make it possible to reduce the cost of living, therefore working hours. In any case it would not have erased the taste for synesthetic experiences, which Marinetti describes. His menus suggest the "consumption" of meals with eyes and/or with the smell, sometimes without eating anything.[5]
Beside of the food, recipes, or rather "formulas" as the Futurists called them, often described the atmosphere and the mood. The attention is fulfilled with the setting of the dining room and the table. Notable are the rich ceramic production of Tullio d'Albisola, the graphic and chromatic research by

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[2] *Fantasio*, 1st september 1913
[3] *Comoedia*, il 20th Jenuary 1931
[4] Marinetti stated that it spoiled the ... "the lively spirit and the passionate generous intuitive soul of Neapolitans who, in eating it, develop their typical ironic and sentimental skepticism, which truncates their enthusiasm often."
[5] Marinetti and Fillia, 1932, "Musical autumn lunch".

Medardo Rosso and Fillia in menus and the advertising billboards by Depero and Prampolini. Advertising graphic was the real invention of the Futurists. The "launcher poster" advertised products of food industry that involved actively the Futurists also in planning stages which anticipated the contemporary developments of Design. They understood the importance of the packaging and the marketing, with unforgotten inventions such as the Fillia’s spiral of the “Amaro Cora” and the Depero’s bottle and shade of Bitter Campari (fig. 1).
An interesting demonstration of the enduring involvement of Futurism in the food industry is *Il Poema del vestito di latte. Parole in libertà futuriste di Marinetti accademico d'Italia*[6]. The pamphlet, which was illustrated by the young Bruno Munari, was published in 1937. It was a promotional of Lanital, an autarkic textile from casein, produced by SNIA Viscosa. The booklet demonstrates through the advertising activity, the relationship of Futurism with the industry, which was the best expression of the machine’s world.
The Futurist cuisine is characterized by irony, imagination and creativity, even colour (fig.2).

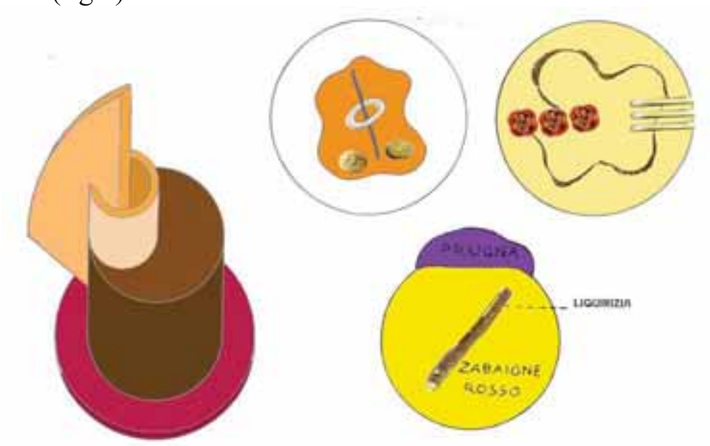

fig. 2 - Futuristic food design: the contrast of colour should increase the dishes appeal as pleasure for eyes. Some recipes describe the “layout” of food in simple pen drawings; the colouring stresses the concept of eatable art that anticipate contemporary trends.

The two most popular dishes are the Nicola Diulgheroff’s “Pollofiat”, a roasted chicken with balls bearing stuffing that give it a unique metallic taste, and the “Carneplastico”, a high meatloaf stuffed with vegetables with a sweet-salty taste and a vaguely phallic shape that enhances the plastic potential of the culinary art (fig. 3). None of them attracts for its colours,

[6] *The Poem of the dress of milk. Free words by Futurist Marinetti, Academic of Italy.*

which are the natural ones produced by food cooking. Other formulas such as Fillia and other painters' ones document a higher attention to colour combinations by the alternation of ingredients. They suggested bold colour compounds according to simple geometric designs, using spinach, tomato sauce, milk, pumpkin puree. In one case it also provides for the correction with methylene blue, anticipating the industrial use of chemical food colours, but generally the futuristic kitchen is coloured by itself, taking advantage from the variety of colours of plants. Meat and dough become plastic stuff of a formal research in which the main subject is not the colour.
The reconstruction of the colour palettes in food dishes contrasts with the aseptic colour design of spaces, where dominated the metallic glow of the aluminium.

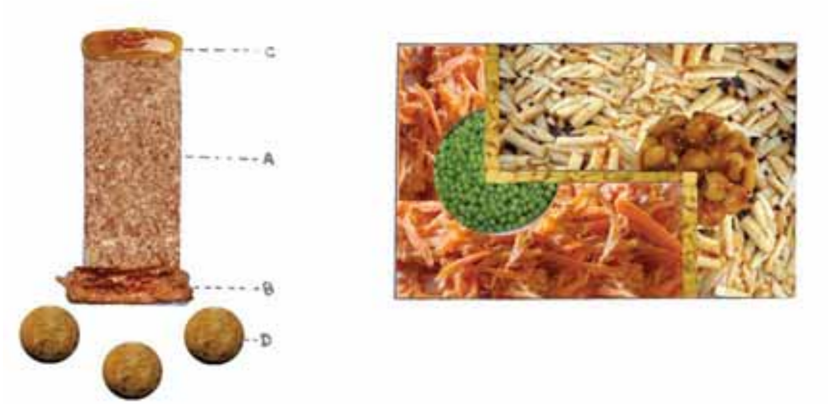

fig. 3 - The natural colour of foods on the design of the recipe of the Carneplastico and the Ortocubo.

2. Interior Design as a food background

One of the important demonstration for the Futurism and for that "reconstruction", which had to include gradually the various field of the human experience, was the initiative to open in Torino a restaurant, where the new futuristic foods had to be presented to the public in a futuristic way. For the realization of the scenery that had to host this demonstration, they chose the painter Fillia and the architect Nicola Diulgheroff. The purpose was the transformation of Angelo Giachino's restaurant in a proper place for the diffusion of the futuristic cuisine. The name of the restaurant, named by Marinetti at the end of the Circuito di Poesia (The Circuit of Poetry) between the futuristic paintings at the Galleria Codebò, was Taverna del Santopalato (The Holy Palate Tavern). Fillia himself declares in an interview that: "*first of all I ask you to notice that our initiative and our activity for the opening of Santopalato has entirely artistic purposes, creators and engines of an our* *culinary theory. It is not about a Diulgheroff's speculation nor mine. We will simply give to the Tavern a futurist mark… The Tavern… will be decorated by architect Diulgheroff and by me with the exact purpose to move in the futurist debate from theory to practice*".

Fillia and Diulgheroff's project in order to receive an organization of different flavours, smells, colours and meanings had to create a space with an atmosphere which had to be the summary of the mechanical modern life.

The Tavern reached a big notoriety even before its inauguration, thanks to the several announcements. The inauguration took place on the 8th March 1931. The main hall was a big cubical box, standing side to side on a smaller one. It was decorated with completely bright, half-circular columns, with big and bright metallic oculus stuck at the half of the height of the wall, which was completely covered by the finest aluminium. This latter was not a simple covering of the wall but it was conceived as a working element of the interior. Fillia wrote in his book "*dominant aluminium, agile bone structure of a new body, complete with the rythm of the indirect light. The light is also one of the fundamental reality of modern architecture and it has to be space, it has to be a living part with the other shapes of the contruction*".

fig. 4 – Historical pictures of the inner space of Taverna del Santopalato in Torino.

The shiny and reflective effect of the aluminium had to support the chromatic presence of the futurist dishes. The colour of the posters, the dishes and the people created an effect of chromatic movement, similar to a kaleidoscopic one. This idea of inner space features the room of various projects, which concern in some way Diulgheroff's food retails in the following years: the bar Cinzano in 1932 and the bar Cora in 1933, both in Torino, as well as the stand for Rivella company in 1934 at the Fiera del Levante in Bari and the Italian restaurant in the Colonial Exhibition in Paris propose again that kaleidoscopic idea of colour and movement, which was generated by reflections of the advertising graphics in the interior.

Diulgheroff's ability in the advertisement, of his own is the bigger part of the advertising posters for different business, from water to boilers, from companies in building field to alcoholic drinks, brings him to have various requests from firms not only as publicist but also as interior designer. The year after the inauguration of Santopalato the same architect designed the interior for a new Bar Cinzano in the First Exhibition of Fashion Design, held at Valentino in Torino. Here the materials the walls are different: metallic grids, mirrors and shiny surfaces. Together with reflective and coloured coverings, they had the purpose to increase the visual effect of advertising slogans everywhere, also on the floor. The main focus is to recreate the kaleidoscopic image of the Santopalato. This concept of space recalls the Futurist poetry of "parolibere" (free words) composition. The chromatic use of walls, which were made of different materials, refers to Van Doesburg's artistic compositions recalling the Neo-Plasticism in a neo-futurist way.

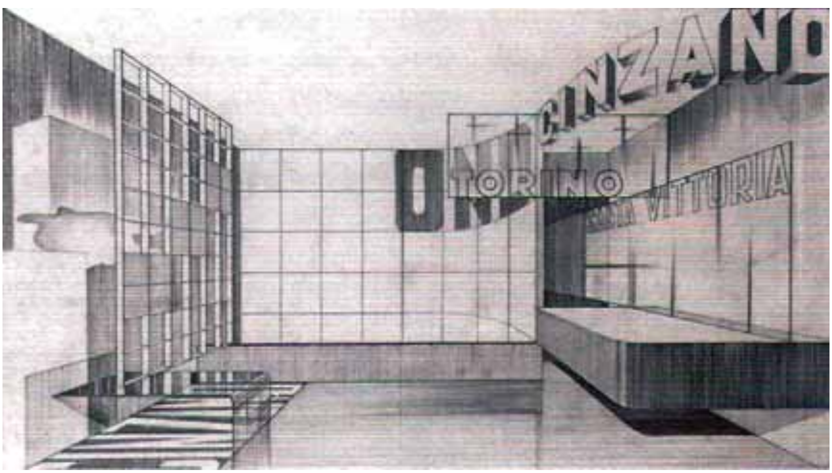

fig. 5 - The project for the Cinzano's bar in occasion of the First exhibit of Fashion Design, held in Torino in 1932

fig. 6 – In order from the top: the interiors of Cora bar designed for the second Fashion exhibition in 1933. The advertising for Amaro Cora in the same time.

During the Second Exhibition of Fashion Design, held in Torino in 1933, Diulgheroff designs the interior of the Bar Cora. The room was narrow and long with the entrance on one of the shorter sides; therefore the architect placed the counter on the long side, on the left of the entrance. Spheres and slogans on the same wall generated the lighting. The wall in front of the counter was painted with orange shades that became clearer upwards and it was illuminated with diffusers, in contrast with the aluminium varnished columns. To use in the best way the perspective tunnel generated by the proportion of the room, the architect designed a half-circular counter with decreasing element and put above it the graphic of the Amaro Cora.
In this case the colour stresses the structure of the space and underlines the graphics, which had different sizes and colours. There is not any

kaleidoscopic effect, but the chromatism accentuates the tunnel effect of the interior.
The only chromatic key in the inside of this space were the big posters, painted by Diulgheroff himself, promoting the Metzeger, the bier of Torino and the Amaro Cora (tonic liquor Cora), the curtains and the various objects within.

fig. 7 - The stand of Rivella designed by Diulgheroff at Fiera del Levante in Bari in 1934.

The Rivella's stand designed by Diulgheroff in 1934 for the Fiera del Levante in Bari, probably never realized, was an example of advertising architecture similar to the one for bar Cinzano. Its constructivist interior had reflective materials and the coloured graphics would constitute a strong advertising call. In this case, the reflective effect of materials would guarantee a kaleidoscopic effect of movement in a chromatic disorder.

The use of colour by one of the most important figure of the Futurism in Torino highlights a choice focused on chromatism to enhance the structure of the mechanical space. Starting from an idea of space and colour influenced by the Neo-Plasticism, Diulgheroff comes to a completely innovative interpretation of chromatic movement that breaks the unity of the spatial box, extending the poetry of the painting to the architecture. The idea of the coloured space recalls the avanguards' culture, but Futurists develops it with grown awareness, thanks to the discussion and debate inside their circles.

3. Conclusion. Anticipating food trends.

The literary documents confirm the importance of Futurist heritage in the contemporary cuisine. Provocateurs experiments of Futurist artists, who improvised cooks, left a mark in the renovation of food industry that is recognizable in developments of the Nouvelle Cuisine, the Molecular Cuisine and in today Food Design. They also marked with their implicit desire to elevate the cooking to a noble art, equating it to literature and main formal arts.

Recipes and menus emphasize the importance of colour in the gustatory synaesthesia, involving not the taste of the food, as well the whole mood of the room in which meals were consumed. The comparison between the formulas by different artists shows a different approach depending on their prevalent training.

Of course the more "colourful" recipes are those by painters.

In Futuristic cuisine, the use of colour is not a feature in itself, because the colour is only one among five sensorial perceptions, which affect the mood together with the interior that backgrounds the eating.

The role of the colour and in this kind of shaping of the interior of food retail is the element which balances the static space and the chromatic dynamism of the inner design, based on light games, and the reflections of the colour graphics, of food and the table set on the tinny walls.

The food is just the stuff of a global art.

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ntroduction

s article wants to study the concept of local color in its representations and fashions that come with it.
will consider the local color in its heritage process through images, writings, between artistic production
ertising production.

e very specific example of the Touquet Paris-Plage provides the opportunity to explore this question.
will lead our analysis through a comparative study of various representations of the station at impor
ments, prior and contemporaneous to the station birth, until the interwar, its golden age.
ially, Le Touquet Paris-Plage is an urban transplant implanted on pristine dunes of northern France, at
uary of the Canche, between 1880 and 1935. It is the project of a new urbanism all promised to moderr
icated to the leisure society. We know it built for the change of scenery and for the fantasy, nourished
hion and renowned architects. In the beginning, there is nothing except the ambition of a few promoter
ke this uninhabited territory a fashionable resort.

e very name of this station attests to this willpower. It is invented in 1875 by Hippolyte de Villemess
ector of Le Figaro newspaper. It resounds like an advertising slogan that seems to promise a parisian
orted for leisure in this hygienist and virtuous seaside.
ween the late 19th century and the first third of the 20th century, the promotion of this new city is done
press and convenes talent of journalists and writers, poster artists and illustrators. We name this piece
stline "Opal Coast" (E.Lévêque- 1911), it is called the northerly Arcachon or the Channel gar
Verne1927). At the end of the nineteenth century, the first color posters are those of the Northern Railv
ch exalt the attractions of the resort. The interwar sees the proliferation of lithographies for gossip colur
fashion catalog. Those of Marcel Jacques Hemjic, Pierre Commarmond, René Vincent, and many others
"fashion plate" which bring together on the same colorful plane, and as an only pattern, smart figures
n, women and architectures. The color quickly appears an essential relay of this local promotion.

ude Mignot[1] writes "water towns, seaside towns and even the resort towns of the seaside are the strict obve
he Haussmann planning at a time of triumph for Beaux-Arts style". It is a laboratory of urban planning.
would imagine that this local color overflows its classical definition to expand its horizons to the contours
dernity that fashion is an avatar.

Touquet Paris-Plage has had 100 years in 2012. A young city here are some key dates of the early days o
struction: in 1837, Jean-Baptiste Alphonse Daloz, parisian notary and hunting amateur, buys 1,600 hecta
dunes to mouth of the Canche. In 1856 he planted maritime pines that will form 50 years later the inhab
est. In 1880, the first subdivision plan is drawn (fig.1). In 1882, the Paris-Plage station is inaugurated. Se
rs later, 34 buildings are counted. In 1892, the first hotel. In 1901, the first municipal Casino. At the enc
nineteenth century, the English Sir John Whitley via the creation of the Touquet Syndicate Limited, exte
urbanized area in the forest, multiplies equipment, develops activities and hotel occupancy.

Origins of a first local color: a color geography
Touquet Paris-Plage between 1837 and 1912

e first words of colors dedicated to Le Touquet area come from Victor Hugo. By coincidence, he writes it
7, the year A. Daloz acquires its land. Bernay, September 5th, 9am – to his daughter Adèle *: "Etaples*
age as I seek, a fishing colony installed in one of the most graceful small bays of the Channel. (...) All
ts were beached off the sand, black and shiny as mussel shells. (...) From time to time I met, on the
esholds, these worthy figures of sailors who nod you nobly. The sea sparkled in the middle of the G
lliant and jagged, like a silver cloth strip. (...) (In the evening, clouds) then draw in the air of bays, headla
t make the sky like a huge mirror where the sea would reflect with its dark and rugged coastline"

inting, the norwegian Frits Thaulow (1847-1906), Eugène Chigot (1860- 1923), Henri Le Sidaner (1862-19
Henri Tattegrain (1874-1954). This artist colony will be called Etaples Art Colony and will last until 1914
ese painters are the first to fix on the canvas the effects of light, that is why they are the first makers
tigators of the local color.
1911, Edouard Leveque, painter, botanist and writer newspaper "Paris-Plage" describes this local color wit
at meticulousness: "The diversity of tones and shades that goes to sea varies depending on the time of the
es and thereafter depending on the more or less large thickness of the liquid sheet rolling on the sand bottor

e opal which reflections are constantly changing, throws in turn red or green notes, from turn off within
ky shadings and infinitely sweet, our coastline presents this range of still varied tones that delight painters,
ause it allows them to diversify their studies, because she makes them to always treat the same subject,
hout ever producing the same painting. "
s is the sensitivity of the painter and colorist that show here. Edouard Leveque belongs indeed to Etaples A
ony (fig.3).

or words : according to Annie Mollard-Desfour in its color dictionary dedicated to the white[2] "opal is m
e, iridescent and changing tints from the most common variety of opal, gemstone family silica"
descences of opal are at the origine of derivatives such opalescence, opalescent opaliser serving to nua
ferent colors, to emphasize on reflections, flash / 1. speaking of the light of heaven, of a body, water ...
aking of the skin / "

e "Opal Coast", the name given by Edouard Leveque, is an imaginary geography which associates to a co
rd a coastal territory near of Belgium, facing southeast coast English, bordered by the english Channel
rth Sea. Le Touquet is part of this imaginary geography of the Opal Coast.

e year 1911 dedicates to the Channel coast this name but much later "Emerald Coast" for the north coast of
ttany in 1894, "Silver Coast" for line beaches of the Landes in 1905. It was the novel "Côte d'Azur" writter
37 by the novelist and poet Stephen Liégeard that renames the coastal territory of Provence and launched t
hion of a geography of colors for French coasts .... Silver, opal, azure, emerald, ruby or even vermilion ... s
ny color words, precious or semi-precious stones or ore. These words that cultivate color and effect, territo
single color, are competing in their similarity and differences in this race for fame. Assembled together, t
ke lok like a collection. At the end of the nineteenth century, with regard to naming the coast between Biar
Arcachon, "We must - said the editor of Pyrénées-ocean" grab memory of crowds ", hitting their imaginat
che" unseen and not heard ", choose a short name, pronounceable by an Anglo-Saxon (...) reject the aesthet
uetry (exit" Emerald "), and finally do not fear a name" noisy like an advertising ".[3]

they are no less sensitive names which also legitimize themselves in the eyes of artists of that time as sh
phen Liégard or Edouard Leveque. "Azur"[4], it is the sky in question first and then to the Mediterranean S
re, sea and sky come together as to melt the horizon in a single country. Opal does the same but in a differ
y: under the pen of Edouard Leveque or that of Victor Hugo, this coast is described climatically, pictorially
s in Hugo like black or sepia ink diluted in water washing or watercolor. It is a vibrant colors freed of
e, indescribable, without contours. A franchise tone "Azur" goes against the diaphanous and delicate "Op
like a chromatic mythology that oppose the North to the South of France. What outdoor painters contribu
preading in their pursuit of special lights, for some of them bright, for the others veiled. And rightly so,
rusted to artists and writers care to baptize "substantially" as these destinations to give the nobil
vilizing" power of an esthete eyes focus on the beautiful and authentic things. A civilizing color for a na
uninhabited landscape or a talisman-color for the unbeliever who doesn't know it yet, who doesn't live in
we want to inhabit the mind of perfect impressions. Painters and writers thus pave the way for the conqu
these virgin territories deflowering them with their sensitive impressions immediately taken over by

Mollard-Desfour, « Le Blanc. Dictionnaire de la couleur. Mots et expressions d'aujourd'hui, XXe-XXIe siècles », CNRS Editions, 2

al Coast ... a color-territory, but still an abstract color, allusive and elitist in which Le Touquet has b
cribed as "pearl" and it is through the relay of advertising image, its mass distribution that will be rooted
collective culture that imaginary.

1- 1881 : map of Canche bay highlighting
metric urbanization project


Fig. 2 - 1871 : Charles-François Daubigny,
Boats on the coast in Etaples


Fig. 3 - 1888 : Edouard-Lévèque,La Canche inTouq

Local color: the emerging knowledge of advertising planning.
ample: the red of the shrimp fisherwoman and the small caddy.

the early twentieth sièclees, Northern Railways depict ont heir advertising posters subtle blend so
turesque images of local life and new landscape of the resort. Informations are often the same: "The Touc
is-Plage, 3 hours from Paris, 4 hours from London, Northerly Arcachon, 800 hectares of pine forest
side / Golf, tennis, horse race, pigeon shooting. " Invariably, a shrimp fisherwoman in the takes palce
eground and seems the station guide, feet in the water or in the pine forest overhanging the sea (Louis Tau
obert Boullier). The intermediatery ground introduced the beach lined with villas or pine forest scattered v
roofs of new cottages. In the background the huge sky with large fleecy clouds. The red petticoat is visua
y present. By its liveliness, it showcases the subtle sweetness of the sea (Louis Tauzin – fig.4), or when
ltiplied, redraws the invisible path that leads to the beach (Robert Roullier 1905 – fig.5). The red petticoa
important visual element that becomes leitmotif of the local culture - here shellfish - in this new environm
he resort. This is also a graphical discovery because it seems that the famous red petticoat was selec
ause of its bright color that acts like a magnet on the eye. Archives and paintings (fig.6, 7) attest to this sl
omatic arrangement. Indeed, costume can be red, that of verotiers or fishermen, but it also said that
mp fisherman has austere garment.

- Around1900 : Louis Tauzin,
uquet, poster for northern railway

Fig. 5 - 1905 : Robert Boullier ,
Le-Touquet, poster for northern railway


Fig. 6 - Henri Adolphe Louis Laurent,Shoreline
Scene, Painting.


Fig. 7 - reconstitution: fishing costume
http://www.lesbonszenfantsdetaples.f
les-costumes.html

garding the resort, it does not derogate from the slogan that characterizes it. On these posters railways,
nd in its opalescent waters and skies, we perceive the seaside urbanization facing the sea. The skill of
ter designer is recognizable by the arrangement of the colors used advertising discourse and we a

eed, nothing better enhances the red little man that the green forest and the pale blue sky. And nothing
ify it. Complementary colors whose visual efficiency isn't ignored by advertisers, we have already poin
. This red, one will find it countless times on other posters at the same time.
e pine forest and dunes overlooking a magnificent cloud are stylish decor of the background of the poster.
is described in the title of the poster ... missing seaside villas, the sea and the beach. We guess them.
lists "Golf, tennis, race tracks, beach, pool, casino Beach, Forest casino." This graphic relief and chang
tent show that the Touquet Paris-Plage is gained fame , on first quarter of the twentieth century, and that
ertising speech, which adds the descriptions of local and shows the urbanization, we move gradually t
nd message "signing". This poster will be published and distributed 45,000 copies in Paris. The small ca
cially became the logo of the city in 2013 (fig.10), a year after its centenary. Rouge in 1925, today it
ome blue. This is not a " opal blue", not a "local blue", that of english Channel or sky, it is blue that one co
"navy" that is not unbecoming for institutions. The gradient seems a play of light that supports the sta
gan of the "light source". The polychrome Golden Shield (fig.8), azure and silver accented with red
ouard Levêque wished it was "its mark, seal, its personality, its" I ", leaves room for child appears of the
dy. Daniel Fasquelle, Mayor of the station says "this is not just a logo, it is also our brand. When we see
dy, we will think immediately in Le Touquet. "The little caddy will be declined in all forms: T-shirts, c
gs, pens, pads sent to various media, on cars of the city ... In short, anything that will affect almos
irectly Le Touquet, will not come out of the station without being accompanied by his little blue caddy[5]. "

re we are witnessing, over a little more 100 years, to the factory in this local color through the painters
strators, journalists and writers, advertisers, contractors and industries. What Caroline St. Pierre cou
ong the heritage process.[6]

6- 1894 : Robert de Guyancourt, ldry forTouquet Paris-Plage

Fig. 9 - 1925 : Edouard-Abel Courchinoux, The little caddy, poster for the northern railway

Fig. 10 - 2012 : the logo of the city

Local color in social chronicles and the fashion press of the Roaring Twenties: the gol e of the "ideal city"

ombed, washed, raked, Le Touquet gives at first glance, with its very green forest, its daubed cottages
dens drawn a line, the impression of a toy for children, small miniature city built beautifully arranged
nmetry, where do behind no papers, no cats or dogs, whose homes would have the uninhabited air, if
ld see the muslin curtains waving, live under the sea breeze
e golf course, one of the most beautifully rugged and that is one of the best maintained, where the v
braces everything together the forest and the sea, offers in the morning hours, a picturesque sight. Jum
pull-over with clear and bright colors put on the emerald links graceful living flowers constantly mov
ne forest does this less attractive to the eye and less picturesque? We do not believe anything. Crossing
se of men and women on horseback, it evokes in turn to turn, and depending on the state of the sky, a ca

e is the description that fashion journalist Camille Duguet makes of the resort in the elegant life in 1928:

roduced by a false impression of lifeless resort with artificial colors, picturesque Touquet Paris-Plage app the writings of Camille Duguet[7] in a landscape vision combining golf, sea, forest and players. A fran on, that of a painting or a photograph with, like a sketch, colored prints, sometimes accurate (emerald lin netimes waves (light colors or vivid), but stung by evocative images (graceful living flowers) that reorga or information in a poetic composit nting inside the painting since Duguet C. works to split its description by introducing the figure of the artis er legitimate observer, esthete and posteritymaker, claiming a subject to paint or subject already painted. H society painter, then two animal painters of the past cent the Opal coast, Le Touquet is proposed as a new subject to paint but far from his savage reality. It insp re painting: hunt or social life. From naturalistic painting of Etaples Art Colony, we evolve to the soc nting. To impressionist, freed, shading stroke of the Etaples Art Colony where opalescent nuance is the m ject of the painting, transcribing the changing and ephemeral phenomena of light, with the post-war, l or is converted to fashion illustration. It becomes a pretext for fashion story. It compartmentalises in sh pattern. These colorful arrangements, executed in solid color and bypassed with dark lines, those illustra painters like Marcel Hemjic, Pierre Commarmond, René Vincent speak about on "thin air", ab roduction of the image and its dissemination in newspapers or magazines. The technique is most often c ography. It involves working with solid color, with a preliminary drawing as mark, and successive passa to 7 for luxurious illustrations.

ne printing offices will be the real precursors of advertising in France, those of Cheret, Chaix, that of Drae nily will join an American publicist in 1920. One of the artists associated with Draeger was Marcel Hem st famous illustrators of the time working for these printings. Marc Martin[8] confirms that "printers freque draftsmen of the illustrated press, whose names are known by the public (...) The connection between art plays extends after the Great War. (...) After the Great War, in 1925 the Exhibition of Decorative Art 25, for the first time, hosts advertising as such in the section of street arts "

e images of the Touquet Paris-Plage - posters and illustrations included in catalogs, travel magazines or a ng - speak about a local color "commanded", designed for advertising and probably executed and reprodu the studio of the printer. It isn't an "in situ" studies as practiced outdoor painters. The places represented y recognizable. Drawing transcribes accurately shapes of buildings. In the sketch, in lines and forms, ognize the influence of the Art Deco style.

ese illustrations reproducible and diffused in number are rising from a mass culture was born. The pla resented are chosen: casino, hermitage, golf course or racetrack of the station. The beach is rarely represe ept to show the bathing costumes. The pool - the largest and most beautiful in Europe - is becoming a sub erre Commarmond). These are the same places described by Camille Duguet. Synchronization of picture ting here. Similarly, it would highlight the sensitive synchronization in the description of Victor Hugo (18 that of the Etaples Art Colony (Charles-François Daubigny "Boats on the coast in Etaples" 1870).

cal color is here dependent and linked to the newspaper industry and to the technical reproduction proces e color is reproduced and is no longer "a rarity." In the commercial intent, it is rare and poetic, and in roducibility it is trivialized.

remember the authentic and timeless shrimp fisherwoman with her red petticaot on the posters of rthern Railway, the theme of the surrounding landscape didn't vary except points of view. Similarly Ma mjic shows on three "different" illustrations (fig. 11, 12, 13) a young woman "fashionable", boyish cut che hat, striped skirt and straw-coloured chandaille. Alternately, she takes place on the foreground of a sc f and tennis, and finally to the casino. What shows Hemjic? A scene of genre? A lifestyle? A fashion pla e local color is no longer in the order of folklore, no longer part of a historical chronicle. This is always a l ctice, but a kind of episode or variety. Variety of decors in the station the woman in yellow seems coll d that the "spectator", in its turn, collects watching these scenes. Not variety of lights of the Opal Co imatic nuances" which, for painters, reinvent a pattern at any time of the day. Local color has change ce-time. On a contemplative time, the nineteenth century, it is transferred in a short and fractionated t

cent (fig.14) confirms this multicolored register. "Marine Pool" by Pierre Commarmond (fig.15) tends m
a bicolor blue and white, but swimmers include in image black , red and orange d
y the drawing composition changes. We would be tempted to say “False variations”… a change in shape
in substance.

cal color becomes fashion color insofar as it can be typed, imitated. This is an enumerable color, collecta
exportable unlike that elusif opal. It is also a color "ideational" because linked to hygienists concepts of
e, this gymnastics France, as called Olivier Chovaux[9], influenced by English sports practices, where the s
light and the sea air are beneficial (solar and pure colors), where physical performance is an excelle
ght colors), where high society is a lifestyle (semitones and radiance). The color coding, color languag
t of fashion principle. Multicolor is also a principle of accumulation which refers to the visual richness
terial abundan
tching these lithographies and understanding the context of its development, we get to wonder which is
del of which? Is Le Touquet Paris-Plage the model of illustrations or illustrations are a model for the stati
s mirror game, this principle of recognition model of imitation and variation, is obviously at the hear
hion dynamics and the condition of its expression and its reception. Marcel Hemjic, René Vincent or Pi
mmarmond build the ideal city vision that corresponds to new social ambitions profoundly elitist. This is
a of perfection as claims to express the fashion image, a composition exercise in a search of the photoge
ing where the color is fragment, where it is episode. In 1928, the Touquet becames a fashion object.

1, 12, 13- Around 1925-1930 : Marcel Hemjic, lithographies - Woman in yellow - tennis, golf and casino

Fig. 14 - Around 1925-1930 : René Vincent , "A L'hermitage", lithography

Fig.15 - Around 1925-1930 : Pierre Commarmo Marine Pool, lithogr

Conclusion :

s article wished to highlight the history and construction terms of the local color of the Touquet Paris-Pl
ween 1837 and 1939, which, from Impressionist painting hotspot, became fashionable resort, and finally e
ion. Now, we could conceive that local color only in its multiple character. This story is a memory of
itory as well as the architecture and landscape of the resort. In its development, its plural character, the lo
or shows that it is involved in the very nature of the station. That's how it is unique and irreplaceable. T
llenge remains to preserve this immaterial heritage and to understand the issues.

h regard to this heritage process of local color, the example of the Touquet Paris-Plage attests to
portance of artistic production from those artists, painters and writers, such as smugglers and designer
itory of identity in which we have demonstrated the importance of color, words, descriptions and ranges
ors between the late nineteenth and the first third of the twentieth century. Those artists that are not fo
ere one would expect them, that birth of the consumer society moves and transfers in advertising trades. A
hould be emphasized again the lead role of press in strategies, distribution and the construction of the lo
or.

vocality territorial identity soon leads to produce simplifications of this type of heritage by summarizing t
most residual expressions. Evidenced by the popularity of multicolored practices or overly bright color on
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8. COLOUR AND EDUCATION

Where is brown?

A discussion on colour illiteracy

Nicoline Kinch

Kolormondo

Colour has always played a crucial role both in nature and among humans etc. Now, technology advances have introduced colour making-decisions in every aspect of our lives. And getting the colour right has become so important that colour trend forcasting is a multimillion dollar business. Just look at the importance of the "colour-of-the-year-industry", with major players like Akzo Nobel, who has Copper Orange as their color of the year, and Pantone appointing Marsala as theirs.

Fig1. Copper orange

Fig 2.Marsala

But using colour is tricky, particularly for the general public. Most people just find it confusing and do not even know that there is a thing called colour theory. For instance, how many can explain the difference between various shades of brown, like Copper Orange and Marsala? Many can *perceive* the difference, but are unable to *analyze* the difference between the two swatches. (I am not talking about analyzes of any advanced kind.) Digging in my own experience, just a couple of years ago I was not able to figure out why brown is not on the colour circle….

People having these problems - probably a majority? - has a kind of "color illiteracy."

The others, those who can "read" colour, are able to draw conclusions like: "*this* brown has lots of red with a little black, while *that* brown is a grey close to black with a touch of orange". They are able to find, understand, mix, and match colours in a reasonably intelligent way. They use all 3 dimensions of colour; hue, value and saturation, although they are not necessarily aware of doing so, but using them intuitively.

Hue and value are easy, but what about saturation? I have been lucky to discuss basic colour understanding with hundreds of designers and related professionals.I have asked for a clear definition of saturation that can be used when explaining to “the person next door”. But what I get are vague and imprecise answers, like: a saturated colour “is more intense”, it has “lots of colour" or "it is pure."

Obviously, answers like these are not good enough. Are Copper Orange and Marsala, our 2 examples above, intense or not? Is one of them more pure than the other? Do they have “lots of colour”? And, by the way, what does a colour look like that does *not* have “lots of colour”....?

As a result, what saturation is, remains unclear to the general public – and many professionals. Within the colour science community tit is commonly understood – but this community represent a very small percentage of all those that work with colour on a daily basis.

I have come to learn that colour experts find it difficult to explain their work to friends and family. And manufacturers of for instance colour measurement products find Kolormondo, the simple and intuitive 3Dmodel of my company, useful, since it helps them to explain their own products to their customers. With the Kolormondo colour globe, the user immediately sees the 3 dimensions (hue is around the globe, value increases gradually further up.The middle grey in the globe has no saturation, the further out you go, the more the saturation increases. The globe is of course a simplification, but it is very forceful for communicating the basics.


Fig 3.The Kolormondo globe *Fig 4. Architect students, University of Mostaganem, Algeria*

A conclusion from our work in introducing Kolormondo is that the basic building block missing for colour literacy is: spreading the understanding of saturation.

One question is: have we (on a macro, public scale) somehow missed the importance of basic ABC understanding colour? Are the colour experts so busy with the complexities of their respective specialized field, that they have overlooked getting the man in street onboard?

And why, just why, is colour still shown flat, in 2D, despite having 3 dimensions? Colour charts, fan decks and colour wheels - are, to my mind, a mystery. Imagine that kids would never be thought that the world is round. Looking at maps, they would regard San Francisco and Tokyo to be in different ends of the world. They would get lots and lots of other things wrong too, as a consequence of this malconception.

Fig 5: Is San Francisco and Tokyo in two different ends of the world?

And, finally, does it matter that the general public does not understand, and/or cannot explain, the basics of colour?

Yes, it matters that there is a wide-spread colour illiteracy. In the professional world, huge resources are wasted in production in all sorts of industries due to problems in understanding and communicating colour (let alone all the advanced technical problems related to getting a colour right). And, as cosumers, I think you share my experience; how hard it is to make the right decisions and get colours right and be the proud owner of something you will use and love for a long time!

Teaching color: the Master in Color Design & Technology

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Abstract

At the end of March, thirteen students, coming from all around the world (Italy, Australia, Germany, Egypt, Lebanon, Colombia), concluded the first edition of the Master in Color Design & Technology. The Master, organized by Politecnico di Milano and Università degli Studi di Milano, aims to provide in-depth training in the complex field of color design and technology, to form professionals able to use color in creative and industrial processes and in numerous application domains.
The program is organized in two separate learning phases. Four teaching modules compose the first theoretical phase, while the second part of the master consists of five project works, referred to typical color design scenarios.
At the end of all the modules, students are called for an internship in one of the companies or research centers related to the master. The hosting companies operate in various sectors: chemistry, fashion, product design, and measurement instrumentation as demonstration that color has a multidisciplinary nature and many different applications.

1. Didactic of the Master

The didactic is organized in two phases. Four teaching modules compose the first theoretical phase. Color culture and history are introduced in the first module, together with an overview about the aspects of perception that are the basis of its complexity. The second module is dedicated to colorimetry and color atlases. The third module is dedicated to the digital color: the theoretical and practical fundamentals to manage, display and reproduce digital color contents on different media are provided. The last module describes the profession of color designer through examples and case studies, in various professional contexts.
In order to practice the gained theoretical knowledge, the second part of the master consists of five project works, referred to typical color design scenarios. The first module is about communication, where students are asked to interpret the color in the context of publishing. The second module deals with fashion design, while the third module focuses on the chromatic planning for innovative retail spaces designed to ensure a harmonious relationship with the values coming from the brand and the corporate identity. The fourth module is about product design, and has the purpose to acquire methods and operational tools in order to design and develop proposals for the chromatic industrial product. The fifth module theme is the relationship between the color in urban spaces and the meanings of the human interactions that take place within it. The discussion focuses on the aesthetic upgrading of buildings in modern construction, to solve their visual impact.
In the following, details about the didactic are given. Interim checks on students' learning progress are scheduled both for the theoretical part and the project works, where they have to work in-group to present a final project for each module. After

the internship, they have to provide a final report considering goals achieved and skills developed during the experience that will be judge by the academic board during the final exam.

1.1. The theoretical fundamentals

Perception and color history

The aim of the first module was to present aspects related to culture, history and color perception. The use of color in motion picture industry and in photography has been shown. In the field of cultural heritage, different techniques are used to measure and monitor the conservation of color artwork. Another important aspect considered in this module is color perception. The perceptual mechanisms that affect the color and vision in general, such as simultaneous contrast, assimilation, color in context, have been examined in order to enable the students to recognize and design them.

Colorimetry and color systems

Although color is a subjective characteristic, the color of a surface or a light source has to be measured, communicated and represented in an accurate way, to be clearly identified. The starting point, however, is the human visual system, therefore an overview about the physiology of the vision has been presented. Then, lectures had addressed the theoretical basis of colorimetry, photometry and radiometry as well as the color atlases, an alternative way to select, represent and communicate color. The module presented the essential technical skills that are the basis of the color designer, whatever the application areas on which it will choose to specialize in the future. The fundamentals have been presented both through frontal lessons, and practical or laboratory activities. Students have been encouraged not only to understand the laws that govern, i.e. a spectrophotometer, but also to learn how to use it correctly.

Digital color

With the diffusion of new technologies, more and more aspects of communication and color reproduction are becoming digital. In this module theoretical and practical fundamentals for manage, view and reproduce the digital color applied to different media have been provided, with particular attention to the limitations and problems associated with the use of different devices (scanner, camera, monitor, printer) and color profiles. Beside to the description of the common digital workflow, some hours have been dedicated to innovative topics as color in stereoscopy and virtual reality.

Color applications

The success of a project that requires the conscious choice of colors depends on the experience, the preparation and the diligence of the designer. This module showed how the knowledge acquired in the previous modules can be applied in most professional fields and applications, through examples and case studies deriving from different contexts: marketing, visual communication, restoration of cultural heritage, photography, architecture, product and lighting design and more. A week after the beginning of the Master, in Milan started the Design Week, one of the most important world event related to the topic of design. The event was an important occasion for the students, who were asked to actively participate, looking for future trends in colors and finishing and reasoning about the change in the use of colors, in terms of decorations and schemes, from 1950s to now and more.

1.2. The project works

Color for communication

This module focused on the function and communicative dimension of color within the project of Communication Design. Each communicative artifact arises from a series of choices that fit into a well-defined design process. The design and implementation of a brand start from the visual identity (name, brand, logo, lettering, packaging, integrated communication) that ensures the recognition and affirmation of the company. It is clear the importance of color in this strategy: the visual identity is built on the evocative and persuasive aspects of the chromatic language.

Fig. 1 - Project Work "Color for communication" teachers Elena Caratti and Elisabetta Del Zoppo. Works of Salma Hussein and Tanja Polegubic.

Color for fashion design

This project work is dedicated to the study of the color texturing in fashion with the aim of being able to offer the same product with different color variation, in order to reach culturally different markets and to offer the sensation of a personal choice to individual consumers. The starting point is the construction of the color palette, composed by individual colors, for the fashion collection, combined in two or three main approaches in relation to the messages conveyed, their aesthetic and social characteristics. The basic concepts of pigments for dyeing and printing textiles as well as the quality standards for the marketing of fashion products have been presented: clothing, footwear and accessories.

Fig. 2 - Project Work "Color for fashion design" teachers Nello Marelli and Renata Pompas. On the left work of Francis Wild. On the right, work of Alba Pedrini and Veronica Sarbach.

Color for interior design

The project work on interiors design is dedicated to the analysis of the application possibilities of a chromatic design, for the creation of innovative retail spaces, that can ensure a harmonious relationship, with the values from the image communicated by the brand and corporate identity. Starting from practical applications, examples of different approaches to retail design have been shown, proposing a new type of commercial space (permanent or temporary) where the color is integral part of the experience design.

Fig. 3 - Project Work "Color for interior design" teachers Arturo Dell'Acqua Bellavitis and Lorenzo Morganti. Work of Suheir Darhouth, Beatriz Travieso and Joni Kirk.

Color for industrial product design

The aim of this project work is to develop a methodology to design a real product (a De Longhi coffee machine in the specific case) through the simulation of a CMF project (Color/Material/Finishes). All the methodical phases needed for the definition of the product identity have been considered: study of the market (position, competitors...), study and definition of the target, study of CMF trends in the sector and creation of CMF scenarios. The CMF responsible for the De Longhi group taught to the class about tendencies, brought color samples used on the market and a new prototype ready for the commercial launch. After this first part, students have gone through the proposal phase with the design of colors, materials and finishes to apply to the new product. The final output for the presentation has been shown also to the responsible from De Longhi that integrated the notes of the teachers with comments based on the experience on the real market.

Fig. 4 - Project Work "Color for product design" teachers Stefania Perenich and Francesca Valan. Work of Costanza Fausone and Ilaria Sarà.

Color for urban space

This part of the master program dealt with the close relationship between architecture and urban space. The aspects related to the interaction between the human being and natural environment has been analyzed. It has been highlighted the role of the "perceptual project" for the growth of civic and urban identities. The module analyzed the issues related to the phenomena of perception and color in the urban scale by providing theoretical and procedural tools with the support of pictures, cognitive maps and case studies.

Fig. 5 - Project Work "Color in urban spaces" teachers Giulio Bertagna and Aldo Bottoli. Works of Sandra Niggl, Simona Troiano, and Sara Ubaldini.

1.3. Empowerment

A number of hours of the master program have been dedicated to the company empowerment: some of the companies (NCS, Barbieri, Mammafotogramma, Flukso, Barco, X-rite, Konica Minolta, Fontegrafica, Mantero, Missoni, Elementi Moda, F.lli Giovanardi, Oikos, De Longhi, Nankai Co Ltd, Merck, TIGER Coatings GmbH & Co. KG and Materis Paints) willing to host interns came in the classroom to tell their story and explain why there is the need of a color expert. They also brought devices and materials to show to the students. Moreover, two visits were made to companies that deal with color design: Clariant Color Work and Lechler, who opened us the doors of their laboratories (figure 6). Empowerment supports the student's process of personal and professional growth by developing the ability to form relationships and to work successfully in a variety of dynamics.

Fig. 6 - Pictures taken during the visits to Clariant Color Work (left) and Lechler (right). Images courtesy of B. Travieso.

2. Conclusions

In this paper we illustrated the experience of the first Master in Color Design & Technology. Students coming from all around the world, and with different backgrounds, attended it, as demonstration that color is a key aspect of our life.

The various sectors, in which the companies hosting a trainee operate, reveal the multidisciplinary nature of color and the different application fields.
During the final exams (fig. 7), students showed their project works to the academic board as well as a presentation of the work they conducted during the internship. The hosting company was chosen directly from the students, in order to let them follow their personal attitudes and interests. This was an opportunity to use, from a practical point of view, the theoretical knowledge acquired during the didactics. In some cases, the knowledge derived from topics covered in the master, not directly related to the specific business object of the company, allows suggestions to improve the business workflow.

Fig. 7 - Top row: two students presenting their work during the final exam. Bottom row: the students, together with the directors of the Master and the tutors. Images courtesy of Y. Elhosafy.

We are now working to launch the second edition of the master. The teachers and the organization staff will receive useful information from the students' interviews and from the feedback of the companies involved in the internship.

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for the success of the Master. Finally, thanks to the teachers of the master for their dedication and professionalism.

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Colour harmony in graphic design education. Colour systems based on the CMYK colour mixing

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1. Introduction

Graphic designers using colour in their work have to create a harmonious balance between the various elements in the design – grid and structure, ilustration style, photography, artwork and typography. In graphic design, colour serves three principal functions: it attracts attention, conveys information and makes it memorable. When working with colour, it is important to establish colour harmony, a condition resulting both from the choice of colours and their order in visual field. For a graphic designer the printed colour image is typically produced using the cyan (C), magenta (M), yellow (Y) and black (B) process colours. The four-process colour inks are applied by separate printing plates in the C, M, Y and K sequence in order to build up an image. The CMYK gamut is far from being perfect it embraces approximately 70 % of the colours perceived by the human eyes [1]. However, because of its low cost, the four-colour print is the most common way of colour reproduction in graphic design. That's why knowledge of the rules of subtractive colour mixing and scaling of their hue, brightness and saturation in CMYK system is essential in the proper and effective use of colour. Despite its limitations, CMYK enables building both various types of colour wheels and the development of rules, which make possible not only the satisfactory reproduction of colour, but also the creation of harmonious colour combinations used in different types of graphic projects. CMYK, as well as any of the currently used colour systems, influences the colour structure of images, and its characteristic traits are clearly seen. An awareness of the limits of different colour systems allows the designer to produce work that will be reproduced accurately and as intended.
The objective of this paper is to show the methods that I use teaching colour classes for graphic design students at the Academy of Fine Arts in Kraków and State Higher Vocational School in Tarnow. Working with substractive colour and process wheel is a starting point for creating colour systems and looking for the rules of colour mixing and harmony within the system. Students are exploring many types of gradation scales and basic contrasts of colours based on the works of colour theorists such as Johann Wolfgang Goethe, Michele Eugene Chevreul, Albert Munsell, Johannes Itten and Faber Birren.

2. Colour wheel and colour triangle as basic tools for colour design

Although the spectrum runs in a straight band from red to violet Isaac Newton did the ingenious thing of twisting it into a circle by adding purple to prismatic colours. It became a starting point for the rule of complementary colours which remains the milestone of each colour theory. Adapting Newton's scheme colour theorists developed the concept of dividing the circle into equal thirds – introducing "primary" colours (red, yellow and blue) and "secondary colours" (green, orange and purple) – mixed from equal proportions of two primaries. The problem is that the primary colours must be defined with the greatest possible accuracy – red shouldn't be neither bluish nor yellowish; yellow neither greenish nor reddish; and blue neither greenish nor reddish. But when we compare the primaries in only a few of the famous artists' colour circles – by Goethe, Chevreul, Itten, Munsell, Birren, there are serius discrepancies among their colours. Consequently, the harmonies of the opposites according to different colour systems differ significantly At the same time, the wheel of colours allows only for the specification of the contrasts of shade, not accounting for such important traits as brightness and saturation. It's only the space reflecting the three dimensions of colour that can be used as a foundation for making different colour combinations , which are the entryway to creating harmonious arrangements. It should be also remembered that a sensation of harmony depends not only on the chosen colour combination, but also on things such as ratios in quantity, colourful surroundings, graphical scheme or design, function and meaning, distance from the watcher, lighting, and many others.

3. Colorant and perceptual colour systems

Colour systems based on colorant model are created by equal increment mixtures in all possible combinations of a set of primary pigments (always more than three). Colour are identified and labeled according to the proportions of each primary in the colour mixture [2]

Colour systems based on perceptual model are created as dimensions of equal perceived differencies in the colour attributes. Colours are placed according to the quantities of each attribute and the model defines a perceptual gamut. The Munsell Color System is propably the most famous example of colour model based on psychophysical measurements of the perceived differencies between colour samples. CMYK system is a typical colorant model based on printing ink mixing formulas, but it can be used for the creation of the perceptual colour system, as it happens with the Swedish NSC.

4. General principles of colour harmony in the works of selected colour theorists

The pioneer colour harmony studies were conducted by Eugene Michel Chevreul (1786-1889) who is most widely known for his law of simultaneus colour contrast. He introduced 6 basic kinds of colour harmonies, comprised in two kinds: harmonies of analogy and harmonies of contrast [3].

1. "The harmony of scale" – monochromatic
2. "The harmony of hues" – analogous
3. "The harmony of dominant colour light"
4. " The harmony of contrast of scale" – monochromatic with different degrees of lightness and saturation
5. "The harmony of contrast of hues" – analogous with different degrees of lightness and saturation
6. "The harmony of contrast of colours" – complements, split-complements, triad, tetrad etc.

The American colour theorist Faber Birren (1900-1988) developed an approach to color harmony based on the Colour Triangle. Birren's triangle is a monochromatic colour scheme which apexes are pure colour, white and black. The triangle generates four types of mixtures: white and black (gray), colour and white (tint), colour, white and black (tone), colour and black (shade). This type of colour order appears on the monochromatic pages of the Swedish NCS colour atlas. Birren suggests eight kinds of colour harmonies based on the triangle: white, colour and black; white, gray and black; colour, tint and white; colour, shade and black; tint, tone and shade; tint, tone and black (or gray); white, tone and shade; tint, tone, gray and shade. He introduces achromatic harmonies or combines differeent hues with similar lightness or/and saturation level.
Albert Munsell (1858-1918) described his views on colour harmony in the book "A grammar of color" (1921), in which he saw a balance as a key factor in determining colour harmony. He described several principles of colour harmony as specific paths through the Munsell Color System. The harmonies include [4]:

1. Achromatic harmony
2. Monochromatic colours of the same value but contrasting chroma
3. Monochromatic colours of the same chroma but contrasting value
4. Monochromatic colours of different chroma and value
5. Complementary colours of the same chroma and value
6. Colours in a diminishing sequence, in which each colour is dropped down a step in both value and chroma, as hue is shifted one step in the same direction around the hue circle
7. Elipthical path around the Munsell colour space

Johannes Itten (1888-1967) developed systematic relationships based on the colour sphere, capable of serving as a basis for colour composition. Colour combinations may be formed of two, three, four, or more colours [5]:

1. Complementary colours of the same value and chroma
2. Fundamental colour chord: yellow/red/blue. The hues of fundamental colour chord can combined with their shades and tints to create a dark-light contrast.
3. Triads – selected from the colour circle so that their positions form an equilateral triangle. The equilateral and isosceles triangles may be also inscribed in the colour sphere.
4. Tetrads – two complementary pairs
5. Hexads – a hexagon may be inscribed in the colour circle or rotated in the colour sphere.

5. Projects of systems based on CMYK mixing

The colour order in CMYK system comes from the rules of mixing the four pigments, and the colour wheel encompassed three primary colours – Cyan, Magenta, Yellow(CMY) and three secondary colours – Red, Green, Blue(RGB). The students' task was creating a colour system with strictly defined rules, however, the wheel which was the foundation of the project could have been the traditional artist's colour wheel (RYB), subtractive colour wheel (CMY), opponent colour wheel (R-G, Y-B), or Munsell colour wheel (Y-R-B-G-P). The consequence of choosing each wheel was the quantity and type of primary colours and the order of secondary colours. Each student personally determined the composition so that visual intervals between neighbouring colours remained similar.

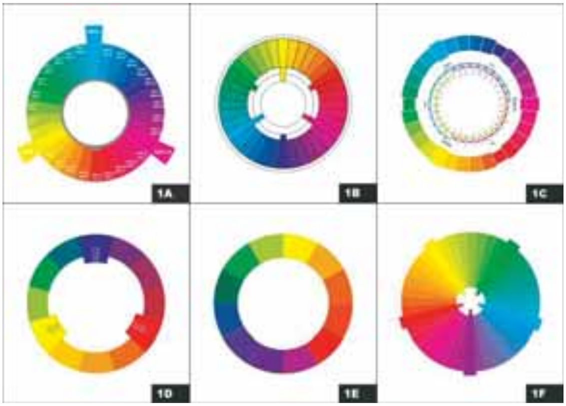

Figure 1 – Colour wheels done with the use of CMY print, based on the chosen amount of primary colours.

Another element of the system were the designs of monochromatic cards. In mixing of the chosen colours it was possible for three or four basic inks to be used. The gamut ran from the maximally saturated colour (from the wheel) to black, white and greys, and could take the form of a square, rectangle, triangle or circle, depending on the rules adhered to. The amount of monochromatic cards was to match the amount of colours on the colour wheel. The entire system was printed as an atlas.

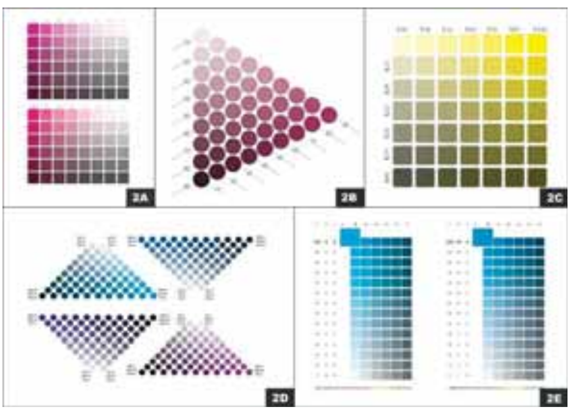

Figure 2 – Various types of monochromatic cards, part of the designed systems

6. In search of the colour harmony. Different types of colour combinations using the colours coming from the systems designed

The goal of the task was both for students to use in practice the basic colour contrasts, which they had the opportunity to see in the works of Michele Eugene

Chevreul, Albert Munsell, Johannes Itten and Faber Birrell, and also creating the rules of colour combinations on their own. The basis of building harmonies was using both contrasts (harmony of contrasts) and analogies (harmony of analogy) of the personally designed combination of colours. Various types of mixing in four colour print were accounted for. Achromatic scale was made through use of black ink, as well as mixing three primary colours in equal proportions. Similarly, in case of changing the level of saturation, which could be achieved either by adding black or the complementary colour. Some of the colours, especially those in which the amount of black was high (over 85%), significantly converged in appearance, therefore the range of colour palettes was under constant scrutiny. During designing, the students over and over compared the look of the colour on the computer screen with the CMYK printed results. Different sorts of colour combinations were also given special nicknames, such as watercolour, vintage, psychedelic, shabby chic, eco, industrial, etc. The colours were applied both on various types of ornaments, patterns and illustrations, and also in the form of graphic design.
The harmonies included:

1. Achromatic harmonies
2. Achromatic colours with a chromatic detail
3. Monochromatic colours of different chroma and value
4. Complementary colours if the same chroma and different value
5. Complementary colours of different chroma and value
6. Monochromatic colours of different chroma and value
7. Complementary colours if the same chroma and different value
8. Complementary colours of different chroma and value
9. Off-complementary colours of different chroma and value
10. Split-complementary colours of different chroma and value
11. Analogous colours of different chroma and value
12. Birren’s harmony: colour + tint + white
13. Birren’s harmony: colour + shade + black
14. Birren’s harmony: tint + tone + shade
15. Harmony of similar saturation: tints
16. Harmony of similar saturation: shades
17. Harmony of similar saturation: tones
18. Triads
19. Tetrads
20. Hexads

Those are only some of the showcased colour combinations. A systematized order of colours allowed for experiments, at the same time enabling reduction of area of search to groups of colours characterized by the similarity of hue, brightness or saturation. Many of the colour systems created during the exercise was later reused by the students in works on different subjects.

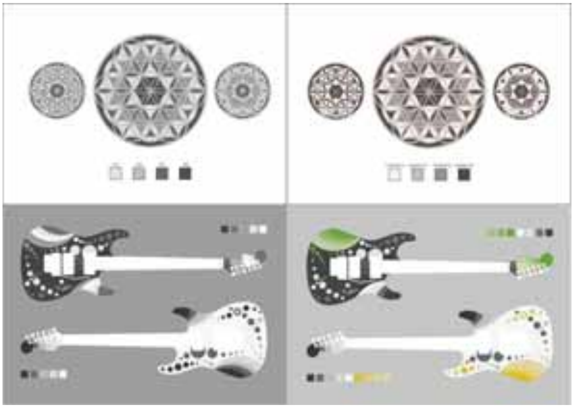

Figure 3 – Achromatic harmonies

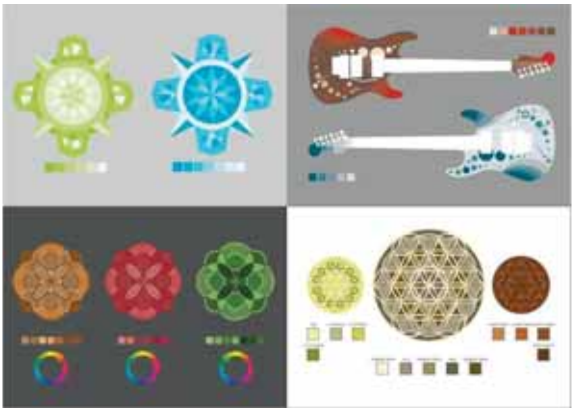

Figure 4 – Monochromatic harmonies

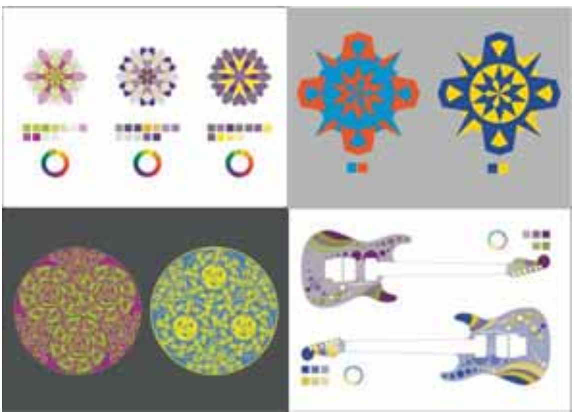

Figure 5 – Complementary colours

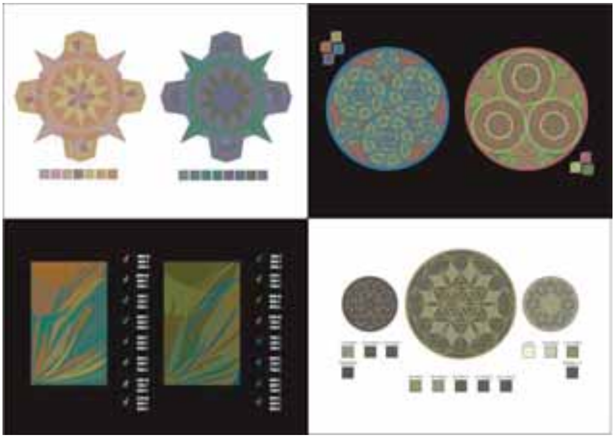

Figure 6 Harmony of similar saturation: vintage

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