Colour and Colorimetry
Multidisciplinary Contributions

Vol. XIII B

Edited by Veronica Marchiafava and Francesca Valan

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Light and Colour: measurement and 3D simulation for a new light of Neptune fountain in Bologna

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1. Introduction

In this contribution an analysis and concept for a new illumination of the monumental complex of the fountain and statue of Neptune in central Bologna [1] is presented. It will be described the investigation phase of the actual installed luminaires and the relieves conducted to find out the lighting levels and the material colours on the site. After the measurement phase, some concepts for a new lighting of the Neptune's fountain and statue complex will be presented, keeping in consideration the request of the client, finishes and the colours of the area. The process end with the reworking of the data and the construction of a digital model of the complex for the production of some videos that display the proposed solutions. The purpose of the paper is to present to professional a case study for a preliminary proposal for the lighting of a complex related to cultural heritage.

2. State of art

The actual lighting on the Neptune statue is made up of a roto-symmetric projector with metal halide lamp with opening of the beam (estimated by the position of the luminaire and the statue) of 2x3°, used to cast the shadow of the statue on the building that host the offices of the town hall (Figure 1).

Fig. 1 (left) - Lighting effect given by the roto-symmetric projector placed on building 02 (Palazzo di Re Enzo)
Fig. 2 (right) - Remains of the lighting system submerged in the basin of the fountain of Neptune

As today, the basin of the fountain and the pedestal of the statue are not illuminated (Figure 2), given the fact that the lighting system installed in the basin have been removed (probably because no longer working).

In the square two different types of discharge lamp have probably[1] been employed:

- High pressure sodium lamp HPS (Figure 3)
- Metal halide lamp (Figure 5)

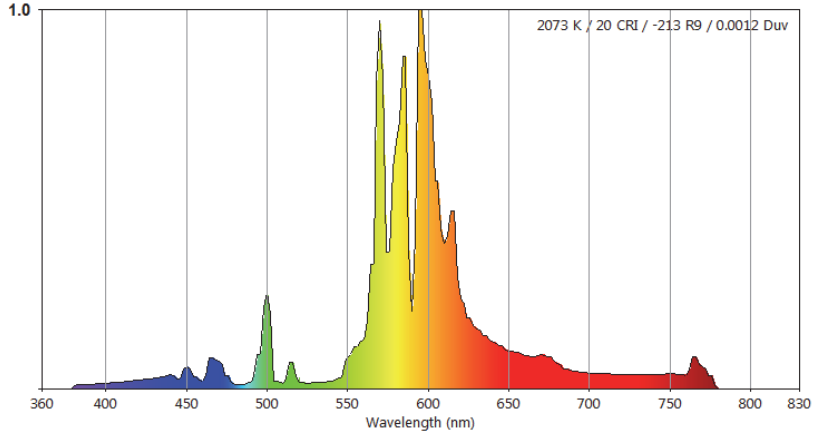


Fig. 3 - Spectral distribution of a high pressure sodium lamp

The first type of lamp is used for the illumination of the majority of building facades (except of the church), where there is a predominance of yellow-green colours for which this kind of lamp grant enough colour rendering (Ra=20-23) together with a high luminous efficacy.
Looking at Figure 5, it is clear to see that HPS lamps grant an increased saturation for yellow-green chromatic samples (even with tint distortion), but at the same time orange-red samples result to be desaturated.
The metal halide lamp grants higher values of colour rendering index (Ra=65) and correlated colour temperature (in the following considerations we will consider a well diffused nominal value of 4000 K) even at the cost of a loss in efficiency.
By looking at Figure 4, it is clear that this lamp grants a better rendering of every colour sample (and most likely, this is why it has been used to illuminate the Neptune statue and may marble elements), even if the deep reds are not rendered at best, compared to reference light source.
Comparing Figure 6 to Figure 7, it is possible to notice that the gamut area (space that encase every colour that can be reproduced by the light source) of the latter is better than the one of the first and that, overall, distortion of the tints appear to be more contained.
Modern LED technology allow to achieve great flexibility in the management of "colour rendering" of the surfaces and the tones of light, preserving at the same time a discrete luminous efficiency.

[1] There was no direct information from the manager of the lighting system

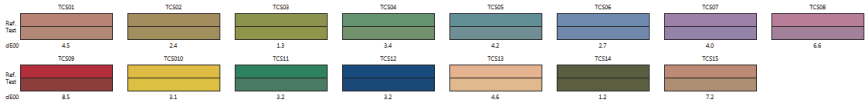


Fig. 4 - Comparison of colour rendering of 15 saturated chromatic samples illuminated by a metal halide lamp and a reference light source with colour temperature of 4279 K (black body)

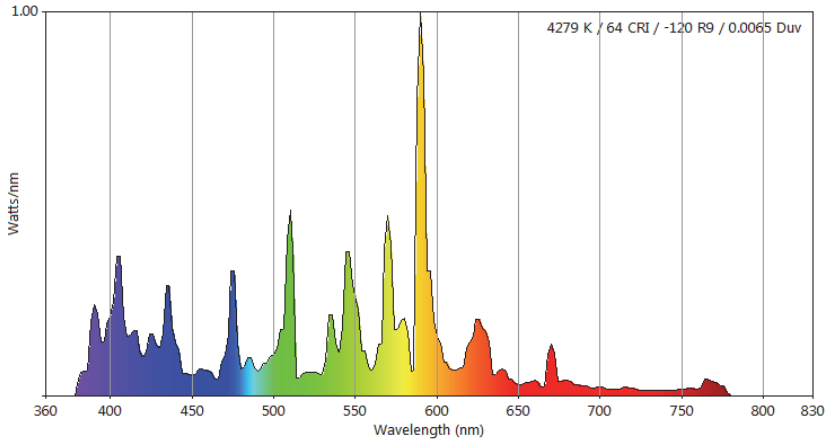
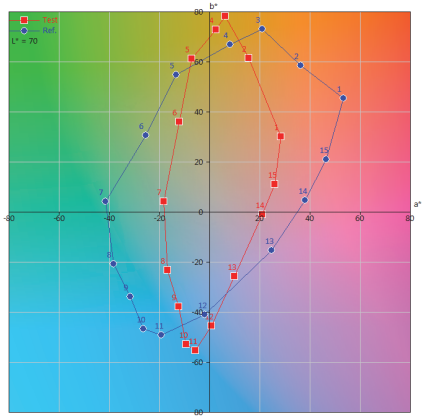


Fig. 5 - Spectral distribution of a metal halide lamp



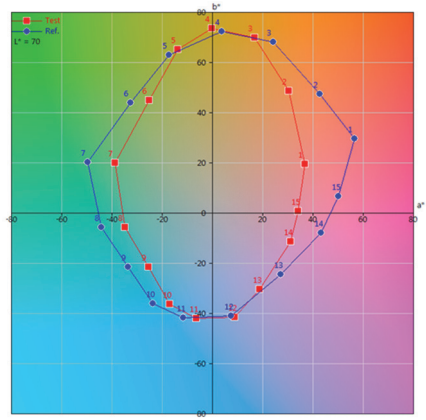


Fig. 6 (left) - Gamut area of the HPS lamp (blue) compared with the reference light source for the 15 saturated chromatic samples of the CQS [1] rendering index.
Fig. 7 (right) - Gamut area of the metal halide lamp (same comparison).

3. Measurement

Luminance measurement have been done in two different days: the 3rd of March 2016 in which the lighting system was completely on, and the 14th of April 2016 when, at the moment of the relief (02.00 am) the accent projector was turned off.
The Neptune's fountain and the surroundings have been measured in all directions in order to evaluate different aspects:

- The level of the modelling (ratio between shadow and light) on the statue given by the actual lighting system
- Evaluation of the hierarchy of different buildings and monuments, taking in consideration different directions of observation (the aim is to evaluate what architectural elements are more visually attractive to the eye of the observer that look in different directions inside of the square, by hypothesizing that high luminance building attract more the stare of the visitor).

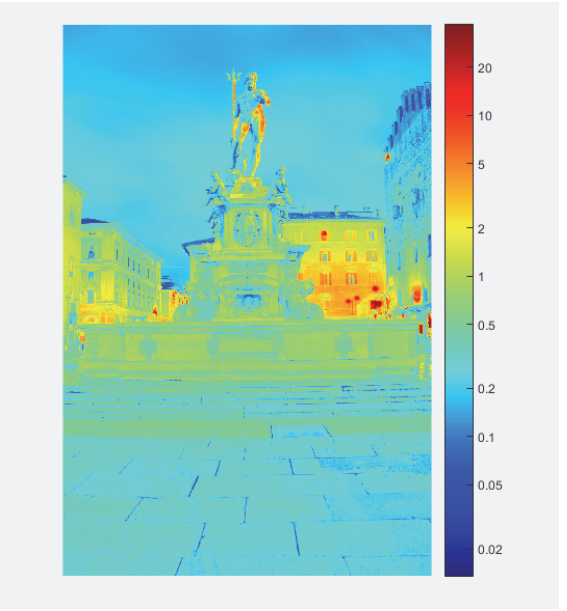
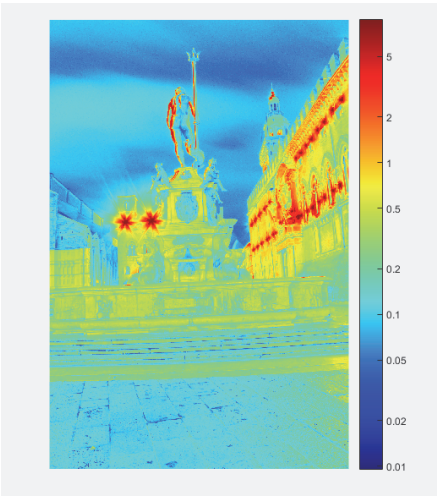


Fig. 8 - Luminance distribution in false colours logarithmic scale (direction toward via Rizzoli)

Looking at Figure 8 (which is the view that an observer would have walking from Piazza Maggiore toward via Francesco Rizzoli), it is noticeable that the average luminance value of the base of the statue, is more or less 0.68 cd/m^2, while the value close to the right thigh increases to 2.1 cd/m^2, up to 2.7 cd/m^2 on the left thigh. This distribution is due to the projector placed on the façade of the building adjacent to the fountain that illuminate the statue projecting her shadow on the opposite building.
The luminance map of the fountain and the statue, by looking from via Rizzoli to Piazza Maggiore is represented in Figure 9, where it is possible to see that the base sits around 0.5/0.6 cd/m^2, the right side of the statue is around 0.2/0.5 cd/m^2, while the left side is definitely more bright with values around 5.8 cd/m^2 (see detail in Figure 10).
The two considered viewing directions appears to be not optimal for looking at the statue.



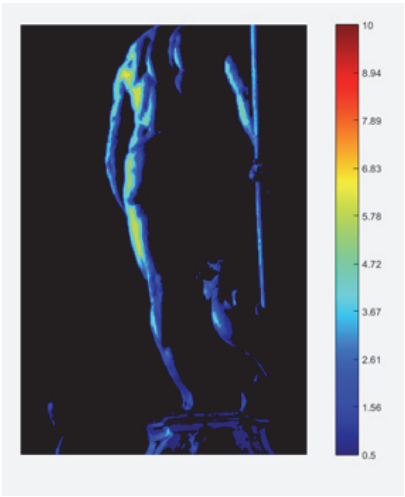


Fig. 9 (left) - Luminance distribution in false colours logarithmic scale (direction toward Piazza Maggiore)
Fig. 10 (right) - Detail of the left side of the Neptune statue (direction toward Piazza Maggiore)

4. Requests

The contractors expressed a series of requests that the new lighting system of the Neptune's fountain should satisfy. The requests can be synthetized in these points:

- Reduce energy consumption
- Control of diffused light
- Glare control
- Valorisation of the monument
- Improved readability of the Statue-Fountain complex in relation to the context (surrounding buildings in the square) and its components (statue of the Neptune, castellum, naiad)
- Valorisation of the water features
- Implementation of dynamic lighting solutions in specific occasions like commemorations and celebrations
- Differentiated illumination between the statue and the castellum

All the request and directions coming from the contractors have been analysed and evaluated and for every element of the fountain and the square, the design solutions that have been proposed will be described in the following paragraph. By the combination of all of the elements, three different concepts of the illumination of the monumental complex of the Neptune's fountain have been created.

4.1. Privileged direction of observation

The three concepts have two different directions that match the privileged paths followed by the tourists and the common users of the square.
The first path is the one that goes from Piazza Maggiore to Via Rizzoli, and the second one is the opposite (from Via Rizzoli to Piazza Maggiore).
The individuation of these two paths was mandatory for the concept of significant luminous effects (visible by the users) and for the definition of the quality parameters

of the lighting system[2], such as the glare control and the reduction of luminance in the field of view for the main direction of observation.

Fig. 11 - Plant of the square with the number of the buildings

5. The concepts

The concept phase articulated through a series of many different proposals (three initial alternatives) that during the development have been modified and reduced to just one, on the basis of the indication given by the contractors and in relation with the ongoing process of restoration of the fountain.
Regarding the illustration of the three initial proposals, a technical report have been produced with all the details regarding the optics and the electrical power implied. This document was integrated with a presentation and a sequence of images (part digital reconstruction and part photo editing) as description of the proposed concepts. To better communicate the choices of the concepts of different lighting solutions derived by the revisions of the contractors three videos have been created. These videos consist of a camera movement that simulate a night walk of a typical user that from Via Rizzoli goes to Piazza Maggiore. Reached the fountain we let the observer take a closer look to the details (such as the water features and the dynamic lighting effects).

[2] This assessment will be the subject of detailed design stage that does not fall within our mandate.

5.1. Illumination of the statue

The first solution presented kept in consideration the actual appearance of the statue's shadow on the opposite building's façade. This element is highly recognizable and characterizes the square, for this reason we suggested to the contractors to preserve this characteristic in the new lighting system.

The concepts provided the illumination of the statue, placing projectors on the surrounding buildings in order to obtain a double effect:

- Illumination of the statue of the Neptune with significantly higher levels of luminance (rising from 1.6 to 6 cd/m2) such as to create a hierarchy among the various architectural elements and draw attention to the figure of the Neptune when observed from the two privileged directions.
- Projection of the shadow of the statue on the buildings surrounding the fountain through groups of projectors that can be controlled independently so to illuminate the figure of the Neptune, casting its shadow in different directions. This solution has been eliminated in a second moment, because the contractor wanted to remove the projection of the shadows, in favour of a "360° vision" of the statue from every direction. For this effect, four groups of projectors have been provided on the buildings 3, 8, 2 and 9. These projectors, all turned on, make the statue visible from all the directions. The projectors are equipped with barndoors and optical systems, to control the emission over the statue preventing light to spill on the building around the monumental complex.

All the lighting concepts intend the statue to be illuminated by LED light sources with colour temperature of 4000 K and colour rendering index at least of 80. Concerning the photometric distribution, narrow beam roto-symmetric projectors, with barndoors (or cylindrical screen) have been chosen to have the best possible control on light; the aim was to reduce the flux dispersed toward the sky and off the shape of the statue.

To satisfy the requests of the contractor, three RGB projectors have been expected in the same position of the white light projectors, in order to realize the coloured lighting during some manifestations of scheduled events, such as:

- Blue lighting for the World Diabetes Day (14 November)
- Blue lighting for World Autism Awareness Day (2 April)
- Pink lighting for the "Rush for the Cure", Komen Italia against breast cancer (22-24 September)
- Red lighting for World Blood Donor Day (14 June)
- Purple lighting for International Epilepsy Day (13 February)

Due to the fact that RGB projectors emit less luminous flux than the white ones[3], the proposal is to lit them all completely (at the same time) while the white light projectors are lit one at the time. When the RGB projectors are used, the luminaires on the castellum should be dimmed or turned off, to increase the perception of the chromatic effect.

[3] It is also important not to exceed with the number of luminaires installed, due to preservation of the appearance of the historical facades around the fountain.

5.2. Lighting of the water features

According to the requests of the contractor, no luminaires could have been installed inside of the basin of the fountain, unlike what happened in the previous lighting system.

The valorisation of the water of the fountain can be achieved only with the illumination of the gushes, through RGB LEDs placed inside specially designed nozzles that can create a laminar jets of water.

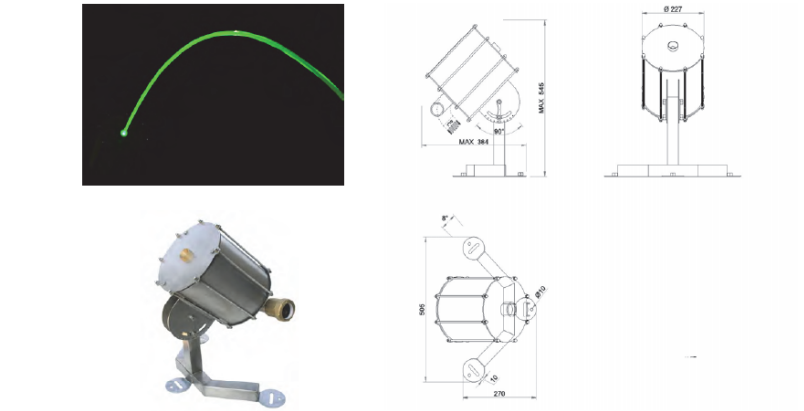


Fig. 12 - Example of device for water features that produce a laminar jet of water, illuminated by a LED light source

The luminous effect that can be achieved through devices like the one in Figure 12, is a water jet completely illuminated and this is due to the fact that the water act as a sort of optic fiber which can conduit light for the whole extension of the jet. This effect is possible only with a laminar flux of water, while a normal jet will not be able to conduit light this way; instead the illuminated portion will be only the one in the direct proximity of the nozzle and then it will decrease quickly while staying from it (Figure 13).

Fig. 13 - Test done at Laboratorio LUCE, Politecnico di Milano of fiber optic lighting of turbulent gush of water.

The use of RGB LEDs allows to obtain coloured light (for instance, during the events), and also white light with a proper tuning of the three emitters.

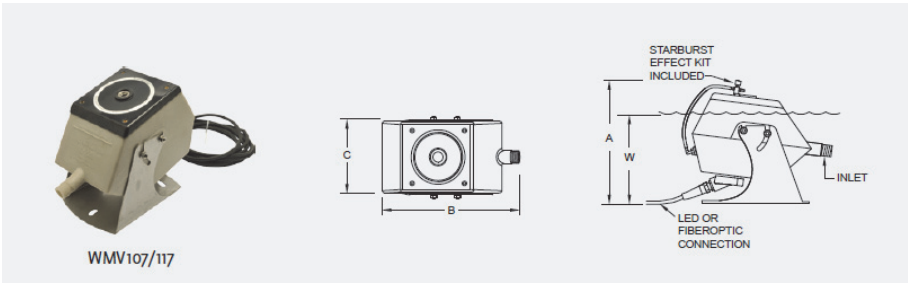


Figure 14 - Device used for the creation of laminar gushes with the detail of the connection of the luminous system

Regarding the mass of water inside the fountain basin, due to the fact that it is not possible to install luminaires within, it will be illuminate by the light reflected of the castellum: direct illumination with the projectors (on the facades of the building) on the basin have not been implemented because of the risk of glare given by specular reflections from the water toward the user.
In order to make the gushes more visible, its scheduled the reduction of luminous flux on the projectors of the castellum and the statue (in well-defined time slots) so to increase the contrast between the background and the water, and improve the perception of the latter. The ratio of the contrast should be at least 3:1.
The management of this lighting effect can be implemented in two different ways:

- All the gushes are illuminated with the same colour decided at the moment of the installation and cannot be changed by the control system.
- The lighting effect is paired with the control system that can change the colour of each jet so that more luminous effects can be cycled through the night

5.3. Accessory lighting of the surrounding building

The illumination of the historical building around the fountain is mainly thought as a series of “lighting signs” on the horizontal surfaces of walking, in correspondence of the lines of white marble encased in the paving of the square, as shown in Figure 15.
Hypothesized characterizing “signs of light” in the square are also the illumination of the windows on the building 9 and 1, with a neutral colour temperature of 4000 K, similar to the one actually installed on building 8. Other than that, above the building 1 and 2, blades of light produced by luminaires with narrow beams (also 4000 K) valorise the battlements.
The aim of this accessory lighting is not to improve the distribution of the illuminances on the horizontal walking surface, but instead to create effects that attract the attention of the observer along the path of the two privileged directions of observation toward the monumental complex of the Neptune.

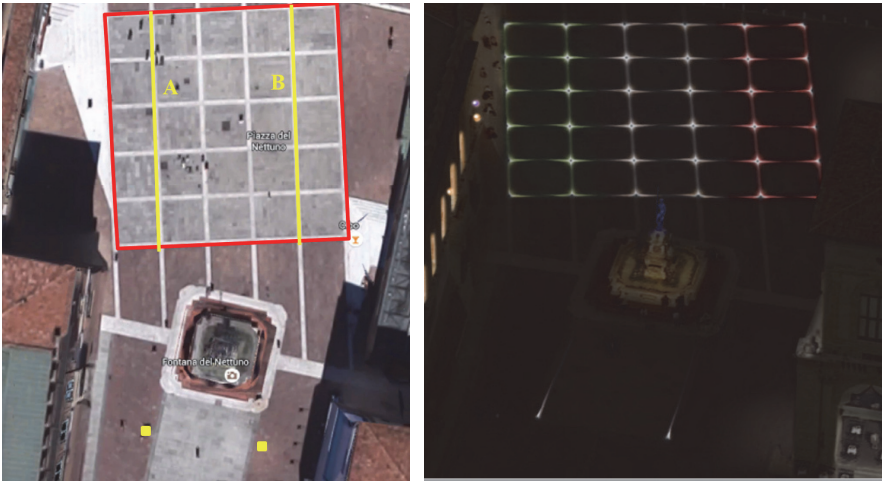


Fig. 15 - On the left: Area in which the "lines of light" should be placed in the first concept presented (on lines A and B and the yellow squares on the opposite side of the statue). On the right: in the third concept, "cross of coloured light" are achieved by placing "blade beam" luminaires on the intersections of the marble encasing on the paving.

6. Digital representation

In the first phase of presentation of the concepts, some pictures were digitally elaborated to represent the appearance of the thee hypothesized lighting installation.
Concerning the 3D model of the fountain, the pedestal and the base, we had a cooperation with the university of Bologna. That team of Bologna took 3D scan of the whole statue. The relief had an average sampling of measurement, but even with that, the final geometry resulted in being of more than two million polygons.
The digital model of the statue has been used to test the values of illuminance with the proposed solutions and the results were presented together with the photo-edited pictures of the concepts (Figure 16).

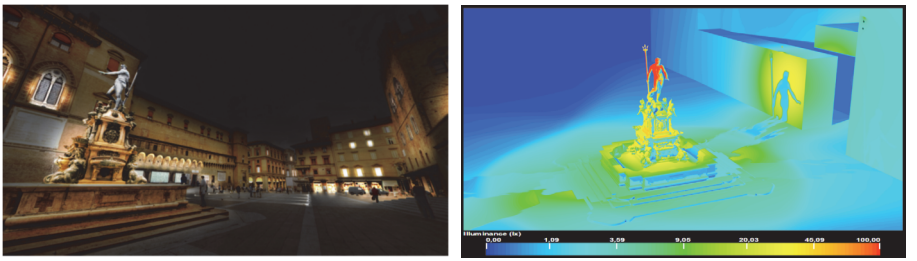


Fig. 16 - On the left: Photo edited picture of Concept 01. On the right: False colour image for the evaluation of illuminance levels given by projectors placed on Building 8 (Palazzo Accursio). The replication of the shadow on the surrounding walls (changing on specific time table) was one of the key ideas of Concept 01.

After the first phase of presentation and revision of the concept with the contractor (that spoke with the municipality of Bologna), the features of the three solution have been represented in short (1 minute and half) videos that, as already said, simulated the path of users through the two main direction of observation.

To create the videos, a digital model of the whole site of Piazza del Nettuno and his surroundings has been created.
Some 3D scans of the buildings were available, but the complexity of the geometry derived by digital scanning, was too high for the reconstruction of the whole site, and would have ended up in excessive rendering times for photorealistic and photometric calculations.
For this reason, the buildings around the statue have instead been modelled with the software 3D Studio Max by Autodesk, using as references, technical drawings, satellite views and pictures of the site, with the aim of keeping the geometry as simple as possible.

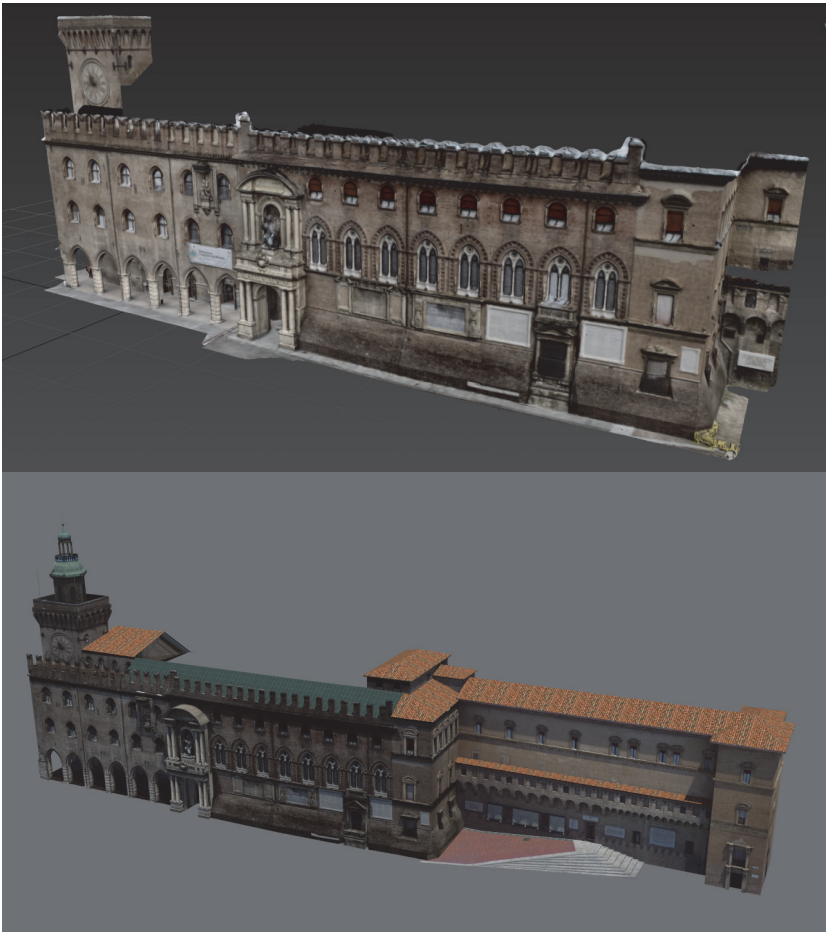


Fig. 17 - Comparison of the complexity of the geometry of the 3D scan (above: 1.399.995 polygons, partial geometry) compared with a modelled version of Palazzo Accursio (87.539 polygons complete geometry).

The textures applied on the geometry have been taken during the two measurement days and also some of them (mostly the ones of Palazzo del Podestà) have been

extracted by the 3D scans made by university of Bologna and specialised websites [3]. Some colour correction of the images has been necessary to unify the appearance of the buildings, due to the fact that the various pictures were taken in different lighting conditions (clear or overcast sky, different times, different devices of acquisition, etc.).

Fig. 18 - On the left: the area that has been modelled for the production of the 3D videos. On the right a frame of the video of Concept 01.

7. Conclusions

The task we carried out was only the metric relief and formulation of concepts. The complete process of design of lighting systems and installations, also includes several successive phases of analysis of the products and technologies available to meet light and energy performance requirements.

Our mandate did not include the complete design procedure, however, the observed phases are emblematic of the first steps of lighting design process; measures (metric, photometric, photographic), study of the site, elaboration of concepts (valorisation of elements, of the main visual routes by the common users, production of visuals, etc.), revision with the contractor and modification of the concepts (depending on the elements that emerged from the reviews) and production of final visuals. This simple walkthrough can act as an example to professional who are faced with a lighting project for the Cultural Heritage.

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