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Smart materials based research for tangible user interfaces

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Abstract

This article proposes an overview on the evolution of interaction design concepts considering smart materials based research. A series of design projects and experimentations, realized within recent years, are here presented with a specific focus on materials performances. Going through design experimentation on chromogenic and kinetic smart materials, the article would try to define three emerging visions that prefigure the creation of physical object used as interactive interfaces with physical users and or responsive systems to environment conditions.
Toward these new design visions disciplinary contributions hybridize with interdisciplinary ones: product design methods work together with interaction design in the Smart Material Interface scenario.
The article investigates on these recent advancements and its correlation with human habitat.

1. Introduction

The term *interaction* means a mutual influence between two or more persons, objects, materials, systems, phenomena, etc. The concept of *interaction* is inherent to the idea of a bidirectional action between the agents who maintain a relationship. Thus the interaction differs from the ratio of unique needs cause and effect.
Commonly used in social and psychological sciences, with *interaction* we define the sequence of dynamic and changing, direct or mediated relationships that are the basis of social relations among individuals, groups, communities, through processes of communication (verbal, written, graphic or gestural, communication).
Within project disciplines, as design and architecture, *interaction* usually means a dialogue which the user sets with a given object, work, device, space, environment or system.

In the digital Era this concept has been taken on the crucial importance by design discipline, as a result of the widespread use of personal computers and software, programmable machines, and GUIs, objects that are able to act and react, devices that allow a complex interaction between man and machine (HCI – Human-Computer Interaction). The set of interaction and interface became an element of the project itself. Firstly it happens in the specific computational field, then in design field in order to facilitate the use of the software and improve user interaction-product. In particular the *interface*, defined as the scene where interactions take place (Anceschi, 1993), has attracted the interest of visual designers, ranging from the simple exchange of information to more complex relationships.

According to G. Anceschi (1993), designing the *interface* consists primarily in shaping the "metaphorical osmotic membrane separating object and user": ideating surfaces, atmospheres adaptations between man's body and the equipment, in order to open "perceptual doors" and "ergonomic bridges toward the action". This includes the design of communication codes with devices, made of textual or gestural or oral languages. Interfaces research hence the concept of "natural interaction", emphasizing how articulations of user requests can be very similar to actions performed spontaneously in the physical world.

In the late 80s the debate on the issues of interface design scholars put in opposition the IT approach and the design one. The IT approach supports the issue of usability, functionality and ergonomics computational of technical artifacts (now regulated by EN ISO 9241). The design approach promoted visual design aspects of interaction, in order to define the *interaction* and *interface*aesthetic dimension. In the same period Bill Moggridge and Bill Verplank[1] coined the term *Interaction Design* to indicate the human-centered approach to experience design, resulting in the relationship between user and interactive digital instruments (user experience).

With Interaction Design term it was defined a branch of industrial design that deals with the design of the interactions, identified as the *ratio* between the user of devices, and the environment.

The first official academic program of Interaction Design was established in 1994 at the Carnegie Mellon University (Pittsburg, Pensilvenia, USA). In 1990 Gillian Crampton Smith founded in London the Design MA Computers connected to the Royal College of Art (RCA). In 2005 Anthony Dunne changed this title in *Design Interactions*. In 2001 it was established in Italy the Interaction Design Institute in Ivrea, exclusively devoted to interaction design, included a specific course of*Building Interface*. In 2007 the Institute of Interaction Design of Copenhagen (CIID) was founded. In 1998 was founded the Interactive Institute, a Swedish research organization sponsored by the Swedish Foundation for Strategic Research. Today almost all design schools have a course of Interaction Design.

2. Evolutions of Interaction Design fundamentals

The short history of Interaction Design as a specific field is living a process of continuous skills upgrading (computer science, cognitive psychology, visual communication design, ergonomics, semiotics, etc.). Many studies helped to define Interaction Design methods and purposes. Most of the studies agree with the position saying that the usability of an interface is not enough by itself to determine user's likings. Usability can be high, because it meets the standards already defined, but does not give sufficient "sensory gratification", or it does not completely perform the tasks that user expects from the application. Due to the increasing complexity that society is facing in the digital age, it is desirable that the relationship between users and "active" technological products should be complete, understandable, enjoyable, engaging and manageable (Norman, 2005). Many scholars have addressed the issue and expressed their views on a possible theory about interaction design, like J. Maeda (2006) whose approach is based on the principle of simplicity, or D. Norman (2005), whose approach is based on emotionality.

In order to define the "quality of interaction", a lot of interdisciplinary researches analyzed phenomena that occur when a user interacts with an interface. The studies have been using physiological measures like skin conductance, electroencephalogram, electromyography, etc. to understand, using experimental psychology methods, which interface or user's profile variables influence the different aspects of the interaction.

The design approach seems to be the most highly user-oriented one. The design approach is based on the awareness that the quality of the interaction concerned with its expressive result. This depends on a number of fundamental choices that have their profound aesthetic nature. The interactive experience of a specific user with a technical device, depends on the involvement of all human senses, as on the evolution of values and meaning of use, within an holistic view of social, material and cultural phenomena (Battarbee, 2007).

Some studies intend to enhance sensory experience with interfaces through the physicality of interactive objects. This is the case of some researches that show the physical and emotional dialogue between an interface and its user. This dialogue is expressed by the dynamic interplay between form, function, and technology (Kolko, 2011). Hallnäs and Redström (2006) stated that interaction design could no longer being considered only as a subfield of computer science, but a real link between basic research in computer science and product applications for new expressive design materials.

Experience design encompasses the design of interaction through the involvement of all the senses and, to include the quality of interaction, also involves many disciplines such as perceptive and cognitive psychology, cognitive sciences (neuropsychology), linguistics, and semiotics. This complex methodological approach has been developed within software design, web applications, and digital devices. Today, experience design is one of the new focal points of research in product design.

3. Smart Materials for Interaction design

The contemporary technological transformations together with the newly developed smart materials are changing the way of thinking and design the interaction between objects and

users.
Smart Materials are radically different from traditional ones (Ferrara, Bengisu 2013 p). They are active, sensitive and reactive to various stimuli, like the modifications of external conditions around them (temperature, humidity, light, electricity, magnetism, pressure, chemical substances, etc.), to which they respond until the stimulus persists. Therefore they are inherently interactive. They act within a predefined behavior with kinetic effects changing the visual aspects of their physicality. They are in motion without using electrical mechanisms. Their interactivity depends on physical and chemical reaction processes that occur at a molecular level.
The interactivity of smart materials has been applied from long time to build 2D human-computer interfaces (as flat screens surfaces). User interacts through remote controls (mouse, keyboard, etc.), or touch screens, with graphical user interfaces (GUI so-called in computer language) that show digital information.
Some recent developments researches focus on the exploration of smart materials correlating digital science with material science and design. Smart materials are used in combination with conventional ones, in order to move the interactive behavior from conventional 2D interfaces to new 3D ones. Based on the characteristic behavior of smart materials (more liable to implementation) you can design objects that serve as tangible interactive interfaces (TUI), capable of changing appearance dynamically reconfigurable as the pixels of a screen, so as to give a physical manifestation of data, to “incorporate” digital information in physical space.
Design a TUI depends on our ability to use the materials to “incorporate” digital information in a physical space. The advantage of a TUI than a GUI is to benefit from the way we perceive intuitively through the senses. The TUI can therefore provide an alternative to the graphical interface and the vision of ubiquitous computing Mark Weiser (H. Ishii, D. Lakatos, Bonanni, Labrune, 2012).
With increasing design potential of physical computational technology, tactile/sensory qualities can be further explored in a way to build intimate relationship between user and object. Physical properties of materials – how they invite user engagement – can provide meaningful insights to interaction design, especially to explore diverse form properties of computational materials. Design exploration with new smart materials can eventually contribute to stimulate the senses and intuitive understanding, so as to make the interaction more enjoyable experience and user-centered. So the project have the challenge of use new materials faced this question: How smart materials can transform product and user experience?
If design will incorporate the potential of these materials in everyday actions, our reality will be much richer and powerful enabler for social interaction. On this subject Iroshi Ishii, director of the Tangible Media Group of the Boston MIT, argues that it is necessary to think “beyond the screen”, and find a way to let people interact with technology in a more efficient and direct way: it is a way to involve the body and sensory testing. The screen information was seen as at the bottom of the sea: you can see it, but not touch it. Instead the work of Ishii focuses on bringing information “on and over the surface of the water”, making them tangible (H. Ishii, D. Lakatos, Bonanni, Labrune, 2012).

Therefore design is facing the challenge of the use of new materials and the question: How digital artifacts designed with new smart materials could transform product and user experience design?
If design will be able to incorporate the potentiality of these materials in everyday actions, our reality could be richer, powerful and qualifying also for social interaction.

4. “Materials that move” in Design Experimentation

Smart materials performances are a powerful stimulus for the project, and they are also promising in relation to current paradigms based on the new sustainability goals, implementation of communication, interaction and human experience. They are great innovative tools to design radically new objects that respond to new consumers needs. On this assumption, a considerable increase of design research focused on the applications of smart materials. They are opening “a turning point in the methods of design” and “new opportunities for research of design and perception”. “The intrinsic dynamics of these materials, the capacity of continuous adaptation, and an harmonic transition make them extraordinary collectors of experience” (Ferrara & Bengisu 2013, pp. 84-86). Most of the design experiments, even if conducted at the level of crafts and do-it-yourself, are useful to develop a series of reflections in order to start new creative challenges combining technology research and experience inspired design.
Their technical complexity referred to a knowledge gap about them in the design field, means that the most successful experiments are those that involve multidisciplinary teams, with different specific tasks (electronic engineers, product or fashion designers, interaction designers, programmers, etc.).
Here reassumed an analysis related to most preferred materials used for experimentation, based on an overview of the last ten years scientific publications:
– Materials that change color, scientifically defined *chromogenic*, skilled in the change of the visual aspects related to the color and transparency, due to different stimuli;
– Materials that change shape, also called *kinetic*, disabled to modify their shape and size for response to different types of stimuli.

The wide use of these materials depends on their commercial availability and ease of retrieval.
The trial of chromogenic materials, widely available in the world market, is driven by fashion design study. Photochromic, thermochromic and chemocromic pigments can be fixed on fabrics with traditional techniques, without need to resort to sophisticated technology and industrial processes. From fashion and textile design experimentation they are spreading in other areas of design, especially product and interior design, but is more manufacturing difficulties for the preparation of composites. For a discussion of the results of experiments with these materials, please refer to the publication *Materials That Change Color*(Ferrara & Bengisu, 2013) which contains a number of case studies related to experiences of experimentation conducted with different types of chromogenic materials for a variety of design.

Regarding “materials that change shape” the currently testing is driven by the research in architecture, although experiments abound within the product and fashion design.
Within this class of materials are the Shape Memory Materials (also Magnetic Alloys and Polymers), Electroactive Polymers (EAP), Electrostrictive materials, Dielectric elastomers, Piezoelectric ceramic, Magnetostrictive (Terfenol-D) and Magnetic Fluids.

Nitinol is the most applied shape memory alloy[2]. It is available on the market in semi-finished components of various sizes for various fields: medial devices, artificial implants, surgery, dental implants as biocompatible material. *Nitinol*alloys has a property that allows the material to undergo deformation at one temperature, then recover its original, undeformed shape upon heating above its transformation temperature. *Nitinol Wire* (also known as Muscle Wire or Memory Wire) is a thin strand of Nitinol of small size, light weight, low power, a very high strength-to-weight ratio, precise control, long life, and direct linear action. Easy to use, it can lift thousands of times their own weight and it returns to its original length when it cools. The direct linear motion of Muscle Wires offers experimenters a source of motion that is very similar to that of a human muscle, providing possibilities not available with motors or solenoids. *Nitinol Wire* may be heated by any means, air temperature, hot water, or most commonly by running electric current through it. Its activation or transition temperature is 70°C (158 °F).
Fabrics incorporating memory wire have the ability to return to some previously defined shape or size when subjected to an appropriate thermal procedure. The temperature at which the material changes in form can be programmed precisely at any desired temperature between -50° and + 100°C. When a similar heating process is applied to *Moving Textiles*, a material that features shape memory wire, the fabric reacts to later changes in temperature (of more than 2.5°C) by shrinking, creasing, changing structure or rolling up. Normal fluctuations in body temperature, therefore, cause no reaction. But clothing made of *Moving Textiles*can be programmed to respond to the transition from outdoor temperatures to heated indoor spaces. Examples are sleeves that automatically roll up and down, a jacket that opens and closes on its own, and a shirt that expands and contracts in both length and circumference. Other possibilities are blinds that descend when exposed to warm sunlight and roll back up when the temperature drops, moving lampshades, etc.
Thermobimetals are a combination of two metals with different thermal expansion coefficient, laminated together. They are available in sheets or strips, disks or spirals. It is commonly used in thermostats as a measurement and control system and in electrical controls as components in mechatronic systems. As the temperature change and rises, one side of the laminated sheet will expand more than the other. The result will be a curved or curled piece of sheet metal.
Reacting with outside temperatures, this smart material has the potential to develop self-actuating intake or exhaust for facades. Some applications in architecture have been documented. Automatically opening and closing ventilation flaps have been developed and installed in greenhouses and also for use as self-closing fire protection flaps, but nothing has been published on the development of this material for building.

Electro-active polymers (EAP) are actuator that converts electrical power into mechanical force. They move in response to electrical stimuli, with the ability to change shape without the need for mechanical actuators. They contract and expand significantly in length or volume. They also react to a few Volts. Are good conductors, with very lightweight, low density, flexibility, but their strength is rather poor, although much higher than the rigid and fragile electro active ceramics. The EAP, have been used in recent decades in application fields such as aerospace evolved in inflatable structures (like the balloons that act as cushions cushioning the blow when a aero-robot lands). Thanks to their flexibility, are used for the realization of *Artificial Muscle Incorporated* (SRI International, a research non-profit in California that launched a company) that emulate natural muscle in bionic systems and biomedical sector.

Finally there are the *Magnetic Fluids*[3], underused at present in design experimentation given their prevailing liquid state difficult to manage. A magnetic iron fluid is a colloidal suspension made of nanoparticles[4] of iron suspended in the fluid. It becomes highly in the presence of a magnetic field. Due to this unique propriety, it can be defined as a material with characteristics of more than one state of matter, the magnetized highly one and the not magnetized and fluid one. Very interesting to understand the quality of these materials are trials of Wakita for Blobs and works by Sachiko Kodama.
Experiments carried out by designers through practical workshop, provide an interesting scenario for basic research that tends to fill the gap of practical knowledge about these new tools in order to understand the technical potential and aesthetic qualities that smart materials can offer during the interaction.
Initially, the trial does not arise an application problem, but it is aimed to understanding the behavior of the material. Free from the search for application solutions, experimentation can reach the performance limits of a material to understand how it works, how can be manipulate for manage its formal, visual and tactile characteristics for his behavior before finally reaching a hypothesis of functionality and interactivity. The experimentations proceed in the following general steps:

1. Know what it has been already done;

2. Understand what you can manipulate by design;

3. Master manipulation of shaping attribute to model the interactions.

Thus, during the trial, the material is revealed to the senses, it informs on its behavior and inspires new applications.
Another step of the experiment is the project of interaction that firstly must establish codes of communication between material-object and user.

5. New Design Visions and Cases Study

Researchers like Dunne, N. Oxman, M. Coelho, A. Minuto, M. Kretzer, Akira Wakita and many others who work in the field of interaction design or computing sciences try to recompose the two aspects, namely computational and operational, designing two dimensions of materials in unison: the physical and the digital. Their objective is encoding information into materiality and to give life to objects and space whose electronic operation becomes tangible and capable to generate a rich, easy understanding, aesthetic and satisfying interaction experiences. As Dunne (2005) states, such an approach intends to retrieve the materiality of the object, reducing the gap between the analog and the digital world since materials used at the micro or nano scale started to be used to construct transistors inside sealed boxes, which gave these objects technical consistency, although they made their operation incomprehensible from that point on. The current approach could improve the affordance of the objects, recovering the material richness, which was lost during the passage from atoms to pixels (Coelho et al. 2007).
Using smart materials, interface design grows with tangible interface that can improve the interaction quality through the physicality, and tray to overcome some of the limitations that digital interfaces have.
The use of smart materials into objects and systems can improve the understanding of the objects during their operation (Ferrara & Bengisu, p.), and it makes pleasant interaction by direct experiences of users using the human senses. It can counter some of the limitations imposed by digital interfaces such as *akinesis*.
Here we will deal with three visions that emerge from design experiments who are placed at a certain distance from the vision of *ubicomp* (ubiquity computing) that search a indirect and mediated experiences where material and the computation are seen detached from each other.

5.1. Smart Material Interfaces (SMIs)

SMIs is a product design vision between computing technologies, material engineering and design that aims to overcome the conventional model of digital human-computer interaction to arrive at a new model of Tangible User Interfaces. By integrating the digital logic to the physical world of objects, Smart Material Interface becomes a way to create a more "natural" interaction and a rich sensorial satisfaction for user. SMIs vision can implement the user-object interaction by new expressive languages and communication channels.
This view was put forth by a team of researchers[5] at the University of Twente, in partnership with Interaction Design Organization. In these organizations considerable efforts have been made to explore the possibilities of applying smart materials in physical interfaces.
Marcello Coelho, researcher of Research Group Human Media Interaction (HMI) of the University of Twente, during his PhD conducted a series of experiments about coupling between smart materials and conventional ones, to creating high-performance composites. Some of his projects have allowed the creation of working prototypes like *Superflex*, a new composite material for a deformable and programmable surface that integrates *Nitinol* muscle wires in a poliuretanic shape memory foam. The experiment is

aimed at the development of a new composite material capable of assuming different configurations for physical computer-aided design. M. Coelho was inspired by the work of Robert Thompson, who explores how human interaction can be the primary force that leads to the transformation of the forms, and to bring to the physical world the same versatility that we find in the digital world, but also support new ways of interaction and communication. The concept of Superflex is very reminiscent of the material developed by Bruno Munari for the Pirelli's collection of toys from the 50s. But, in contrast to that of Munari, Superflex's surface can be electronically controlled to deform and gain new shapes without the need of direct manipulation with hands, but it work by external actuators. The material has been designed as a shape-changing interfaces, also be applied as a device used to record and replay messages by physically manipulating ITS SpeakCup shape to achieve, in the form of computer-aided design.

Another prototypes is *Sprout I/O*, an haptic interface for tactile and visual communication composed of an array of soft and kinetic textile strands which can sense touch and move to display images and animations. It is built from a seamless textile and SMA composite to render a dynamic texture, which is responsible for actuation and sensing, as well as the surface's visual and tactile qualities. Sprout I/O uses a shape changing texture to explore how small shape deformations on a surface can be perceived as a whole and used to communicate. As consequence, this exploration also sheds light on the relationship between the overall shape of an object and its changing surface properties.

This example demonstrate that the application of smart materials can improve the user-object interaction because it confers to the objects a communicative capacity related to their state or to other external information (environmental).

Akira Wakita[6]

The project *Blob Mobility*, from the Wakita Laboratoray at Keio University, uses a fluid, pastel-colored, programmable matter (magnetic liquid named pBlob, i.e. programmable blob) as interface for a physical actuated shape display. The liquid display is manipulated by hardware made of electromagnets and their control circuits, and provides newfound abilities to govern the unpredictable movements of fluids, that responds to the magnetic field, changing shape in response. The designers describe the method of Blob creation, details of the mechanism and the language for transformation control.

This enables the designer to experience organic shape changes geometrically and topologically in real space. According to Wakita, the device "enables us to experience organic shape changes in real space." (xx) If virtual environments have incessantly mimicked real ones, Blob Motility marks an intriguing reversal in which reality begins to emulate virtual space. Some applications are being develop.

Another but more complex design example, which declares to adopt smart materials to build a user interface, is the project of a smart vacuum cleaner by de Bruijn (2011). Describing the applied methodology during design, de Bruijn emphasizes the importance of designing the user experience, which anticipates the full involvement of senses to

facilitate the understanding of the functioning of the object and the design of user-product interaction, based on the model of human–human interactions made of reciprocal communication and reactions to render the experience more satisfactory.
This and other examples of product design demonstrate that the application of smart materials permit the improvement of communication with the product. Through the modification of color, light and shapes induced by stimulus and without the need for screens, since the material itself acts as an interface, it is possible to convey messages and information to the users, for example communicating what is occurring inside the product or how to use it. Smart materials, like chromogenic and kinetic ones, open new windows of opportunity for augmenting the reality of interaction, making it more continuous, persistent, and coherent to feedback (Minuto et al. 2011).

5.2. Responsive Environment

This design vision inspires architecture and landscape concept that enhance users sensory experience and lifestyle.
Architectural product concepts, that include responsive skin, are designed to facilitate well-being through surprise, movement, natural noise management, air movement and natural light dispersion. The interaction happens between environments thought a skin responsive mediation. That can transform to change the interior characteristics of a space in response to people and the atmospheric/lighting conditions outside.
Investigations show the Building with responsive skin as biomimetic of the human or other biological life skin must be designed as a “huge receptor field”, capable of indicating, controlling and reacting to the aggression of the surrounding space. This field has to form suitable values of the components that influence the living comfort in the architectural spaces. It should be composed of smart materials (thermo-chromic glasses, thermo-bimetal elements, memory shape materials, piezo elements, etc.)
With responsive building skin as the outside (or inside) temperature rises, it is intended that the skin will physically peel open, allowing the building to ventilate automatically. With further development, an active method of air intake and exhaust can be developed.
From the many design investigation stands out the Metamorphosis design concepts, by Philips. That have been created viewing the home as a filter to limit air pollution, electromagnetic smog, and industrial noise penetrating our living and working space while letting in natural light, air and sound. The concepts work as a filter between people and the natural world from which, over time, people have become detached.

Phototropia is the name of the thesis project of Edyta Augustynowicz, Sofia Georgakopulou, Dino Rossi and Stefanie Sixt, supervised by Manuel Kretzer of ETH Zürich. It was realized in September 2010 in cooperation with the Laboratories for Material Science (EMPA), in Dübendorf.
Phototropia is a façade that contributes significant reduction in energy consumption by regulating the incoming sunlight into the interior of a residential building. *Electrochromic* and liquid crystal technologies allow the modification of thermal transmittance and view, which are controlled by a model-based plan executive. Except

from operating as climate moderator the façade functions as an interface mediating the dynamics between inside and outside, public and private. The interaction design challenge is how to renew the role of the façade to provide new ways of association between the private environment of the house and the public environment of the street, the residents among themselves and their neighbors, and ultimately the house and its urban context.

5.3. Warning signals or Communicative Clothes

Although any clothing can be construed as an expression of personality or identity, certain garments are more explicit when it comes to communicating something about the wearer. With the incorporation of electronics into clothing, modes of communication through fashion are extended further.

Lorna Ross's models for telephone gloves allow explicit communication through actual conversation.

The MIT Media Laboratory's MEME tags transmit information about the wearer to other tags. Cell phones and beepers themselves have entered the realm of fashion: in Japan, an incredible array of cartoon-character pendants, flashing antennae, and sleek pouches are available for embellishing cell phones, while both cell phone and beeper manufacturers strive to design attractive and trendy cases for the devices. Traditional fashion allows people to express themselves and communicate personal information to the general public; electronics allow targeted communication of specific data to specific people.

Wearer can transform or customize a garment.

Reactivity input how many stimuli a garment responds to. Any physical object is inherently responsive to ambient physical stimuli: wind, collision, gravity, and wear and tear. However, electronics allow computational garments to respond to any number of specific stimuli as well, physical or intangible, from motion (via accelerometers) to sound (via microphones) to transmit digital data (via infrared or serial receivers). The number of inputs can range from zero (no explicit inputs; for example a wool sweater) to one (on/off; for example a light-up LED ring) to many.

6. Conclusion

In the essay, we introduced the evolution of interaction design affected by the emerging smart materials. Our survey about recent material and interface technologies described specific vision design examples in order to conceptualize the emerging material quality of digital artifacts in term of their material effect in use. As an overall observation based on this survey, we found that there is a need for interaction design and HCI research to pay more attention to the on going rapid and dynamic development of new physical materials. It is clear that these new material bring potential for new form of interaction where the physical is merged and blended with the digital.

Questions in how tangible or physical computing interfaces would transform the relationship between users and digital artifacts from longitudinal and socio-ecological perspective, how they could achieve or would lose certain design qualities compared to the interaction with non-digital artifacts, and how designers could strategize design with physical enhanced computational technology to promote sustainable interaction and good experiences.

Based on the review of specific example and design scenarios, we have described three different visions – smart material interfaces, responsive environment and communicative clothes. The design visions are not mutually exclusive but closely related to each other. Each of vision suggests a corresponding design implications and research directions in functional behaviours, performances and aesthetic quality. A suitable interaction design and a frame of meaning.

Both the objects we use in everyday life, both architectures in which we live, from “passive” and “immutable” (as in appearance, shape, size, color, etc.) are transformed into “active” and “changing” due to the materials acts as an interface. Their appearance and texture will change with the same ease and speed with which digital forms change on our computer screens.

In architecture, building surfaces may lose their stiffness, rigidity and immobility, changing their way of being and appearance in relation to the interaction with users and with the characteristics of the external environment, in automatic or intuitive ways; environments will gain sensitivity, becoming “flexible” and “adaptable” to respond easily to change throughout their lifetime.

Objects and architecture, incorporating the digital logic and the open source programming processing, thanks to platforms like Arduino, will integrate their behavior depending on specific customer.

Incorporating a composite entity in both hardware and software, the interaction may be rich in expressive potential and serve new functions that we will be able to imagine.