Chapter 29

ReActive: Exploring Hybrid Interactive Materials in Craftsmanship

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Abstract

This paper presents ReActive, a design exploration aimed at embedding interactivity in traditional materials by artisanal processes. In the attempt to reconciling technology with human experience and tradition, we experimented with artisans to understand how craftsmanship can embrace technological innovations while at the same time maintaining its nature and value. We built samples of hybrid materials, where electronics and smart materials are embedded in traditional ones, in order to make them reactive and interactive. We discuss implications and new possibilities offered by these new hybrid materials both for artisans and users and new perspectives for interaction design.

Keywords: interaction design, materials, craftsmanship, flexible electronics, reactive pigments, user experience, esthetics of interaction

1. Introduction

Electronics has long been associated to technological development and considered a cold, unemotional element. During the last decades, HCI has tried to move towards more emotional and human-centered approaches to technology and electronics, trying to find new meanings to them and looking at the experience they generate [1, 2]. As a consequence, the field of interaction and experience design emerged. Recent trends in these fields are exploring how interaction with smart and tech-rich products can be esthetically pleasant [3, 4], how electronics and smart materials can enrich the product's esthetics by making it dynamic and changing [5] and how electronics and computation can be considered new kinds of materials, also called computational composites [6], able to produce innovative experiences. Such approaches are complemented by the rise of the Do-It-Yourself (DIY) movement, where people experiment new ways to integrate technologies in everyday objects and materials. Technology becomes more transparent to be seamlessly integrated into textile [7], paper [8, 9], and hard surfaces.

Although much has been done in shaping increasingly human interactions with technology, the process of *making* technological and smart objects has been more and more detached from traditional, artisanal processes, heavily relying on computational and machine-based processes like 3D printing and modeling. Technology seems to be far away from the world of craftsmanship, with its values of uniqueness, care for details, high quality and slow-paced, manual production. What if interactive and smart products manufacturing processes could be reconnected to artisanal processes? What if electronics and technology could be treated and approached as traditional materials, used to shape not only new product functions, but also new static and dynamic esthetic qualities of physical objects?

Some researchers have experimented in this field [11], by proposing new ways to merge electronics and traditional crafting activities and materials. We used a similar approach to develop a project, ReActive, in which we tried to explore how to reconcile craftsmanship and technology, with the aim to achieve three goals: (i) studying traditional artisanal craft processes to identify points of intervention with smart materials and fabrication methods; (ii) advancing and enriching artisanal works by adding a layer of interactivity and smartness to the materials of tradition; and (iii) softening technology and smart products by introducing esthetic qualities and values proper of the artisanal world.

Compared to previous experiences, we do not address DIY or artistic movements. Instead, we focus on the world of artisans, to provide a framework that connects hybrid materials to artisanal processes, in order to inspire new artisanal work. Can these new trends really be leveraged and absorbed by artisans, to modify and add new competences and open up new opportunities?

2. The ReActive project

ReActive was a collaborative project performed in collaboration with traditional artisans in the Florence area of Italy, aimed at exploring the potentials in utilizing electronics and smart materials in their crafts. The goal was to try to develop new types of hybrid materials with dynamic appearances and interactive qualities, starting from the traditional materials and processes used by artisans. We identified a number of conductive and smart materials that could be coupled with such traditional materials to make them reactive and smart. The aim was to create new experiences with these materials of tradition, without changing their nature, instead adding a layer of interactivity to them, that still allowed to keep their properties and that could be smoothly embedded into matter by artisanal processes.

In our exploration, we experimented with the following three sets of elements:

- traditional materials: paper, ceramics, fabric, and leather;
- crafting techniques: fusing, painting, knitting (weaving), embroidering, and gilding;

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- smart and conductive materials: conductive fibers, conductive ink, metal leaves, and reactive pigments.

We investigated the results that could be obtained by merging these materials and processes. Samples of new coupling between traditional materials and smart materials/electronics were generated and are described in the paper. Finally, new possibilities opened up by these hybrid materials, possible applications and scenarios transformation for artisans and users are discussed.

3. Experimenting with hybrid materials

Figure 1 illustrates the experiments we performed on different materials. It shows how we embedded conductive and smart materials into traditional materials by artisanal crafting processes.

In the following sections, we describe the experiments we performed on each class of materials, starting from the study of the Florentine artisans' activities.

3.1. Paper

3.1.1. Painting

Florentine paper is famous for the decorative marbling patterns. It is used in many products, from stationary items to the wrapping of small household objects. As a versatile material used in our everyday objects, we wanted to explore ways to add interactivity to this sheet material.

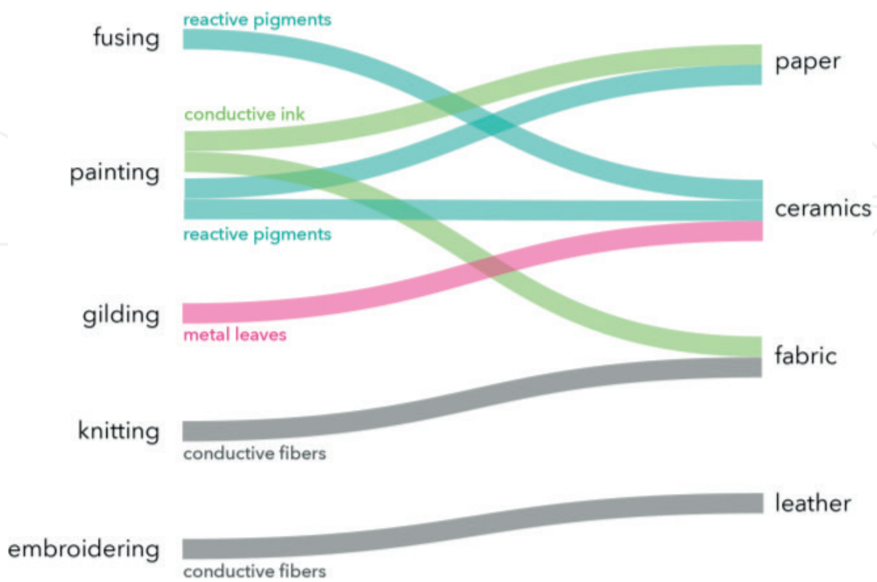

Figure 1. The experiments we performed on embedding advanced materials into traditional ones by artisanal processes.

We studied the hand crafting process of traditional paper making, which involved two methods: first was using marbling technique by 'capturing' floating oil-based metallic paint with paper (**Figure 2**), and second was using pattern blocks to individually press print inked patterns on paper (**Figure 3**).

In this process of decorative paper making, we identified 'painting' with ink as main method of introducing interactivity. Within this method, we explored two types of interactivity. First, we created recognizable and visible interactivity with the use of flexible electronics through painting/writing with conductive ink. Second, we 'embedded' the interactivity into the paper itself—in a decorative form as done in paper marbling process observed above—by painting with reactive pigments such as thermochromic, photochromic, and hydrochromic pigments.

Flexible circuits can be easily created by using conductive ink to draw circuit patterns on paper. Small sensors and actuators can be added to the circuits, as shown in **Figure 4**, to transform a sheet of paper into an interactive material that reacts to external stimuli and user actions (ambient light, pressure, slide, sound, pushing, or rubbing), triggering effects like sounds or light. We explored typical gestures users perform on paper, like folding, rubbing, and touching, and generated responses to these gestures thanks to different actuators. These conductive metallic inks could be potentially used in the marbling process of decorative paper making to create a conductive 'base' (a 'substrate') for paper circuitry. For example, users can create interactivity by adding micro LEDs, sensors, and actuators to the conductive base, and completing the circuit with a hand drawing/painting with conductive ink.

As mentioned previously, we also explored reactive pigments applied to paper by painting and stenciling (inspired by block press printing technique from the Florentine paper maker).

Figure 2. Creating organic 'marbling' patterns using oil-based metallic paints.

Figure 3. Using pattern blocks to print (stamp) colored patterns on paper. For complex prints with multi colors, multiple pattern blocks and inks are used during the process. A full pattern is separated into multiple blocks to allow multi-color press printing.

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Paper becomes reactive to interaction with users (e.g. hand temperature) and to external stimuli (humidity, temperature, and UV light). These reactive inks can be easily applied to the block printing process of the traditional hand making of Florentine paper as well. For example, thermochromic ink can be used to press print selective patterns of the multi-step block printing process as explained in **Figure 3**. An interactive paper would be produced, similar to examples made in **Figure 5**. Upon touch, the temperature of the hand can unveil unexpected patterns of this reactive paper.

3.2. Ceramics

In ceramics, again two explorations were made around the idea of shaping new esthetic interactions: fusing/embedding of interactive elements to the material itself (pigment powder in glazing base), and applying interactivity through visible decoration through metallic gilding. The experimentation started with the observation of the ceramic making process by artisans (**Figure 6**).

3.2.1. Fusing

One of the key processes we learnt while visiting the artisans' workshop in Florence was the final 'decoration' step, which involved hand painting and glazing (**Figure 7**). Starting from this knowledge, we asked ourselves: what if we embed interactive elements such as reactive pigments to the glazing base? In this exploration, we tested the fusing of thermochromic pigments to the glazing base. Pigments were added to the base at incremental concentration

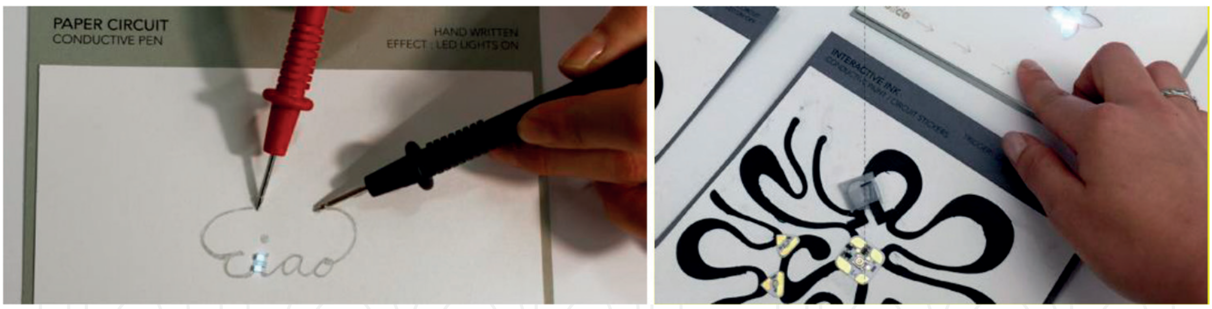

Figure 4. Using conductive ink to create interactivity through writing on paper.

Figure 5. Using reactive pigments such as thermochromic pigments to create interactive decorative patterns on paper by painting and stenciling.

Figure 6. Observing the process of ceramic making of Florentine artisans: painting/glazing, and hand molding a lamp with clay. Many of the ceramic lamps were minimally decorated (no gilding with metallic leaves, etc.), and finished with basic glazing.

Figure 7. Thermochromic pigment powder was added to the glazing base at different concentration for glazing ceramics. However, the thermochromic glaze lost its properties under high heat during the baking process in the kiln.

amounts, as shown in **Figure 8**. However, due to its heat-reactive properties (the pigments turn transparent when under heat), the pigments completely disappeared during the firing process in the kiln.

3.2.2. Painting

Following the unexpected outcome in the previous experiment, we applied reactive pigments to glazed surface of ceramics in order to avoid exposure to extreme heat, which would cancel out all reactive characteristics of the pigment. Interactive pigments such as thermochromic, photochromic, and hydrochromic pigments were painted on tiles as smart decorations. These pigments would change its visible qualities under multiple stimuli (humidity, temperature, UV light, etc.). The reactive pigments can be layered with non-reactive paints/decorations to create various visual effects, as the reactive pigments will appear/disappear under changing outside conditions.

3.2.3. Gilding

In addition to surface application of reactive materials through painting (stenciling), we tested the use of decorative metallic leaves to create touch-sensitive (capacitive) circuits through the process of gilding. These metallic leaves would withstand high heat during the glazing process, and thus would be applicable for the use in ceramics. A quick conductivity testing was done using silver, copper, and gold metallic leaves. Then we focused on creating patterns (organic shapes) that everyday users would recognize as decoration, and not as apparent interactive circuits. Various patterns were made by laser cutting stencil base, and we used gilding technique to apply these patterns on ceramics. Actuators and sensor inputs in miniscule scale were added to the conductive circuitry to generate interactions (**Figure 9**).

By this process, ceramics becomes conductive and can be made responsive to a number of environmental stimuli and user's actions, depending on the sensors and actuators embedded. This new conductive ceramic can be used to generate different types of interactions and applications, from interiors (tiles) to everyday products (pottery). We designed a mug that can change its aesthetics (lights up) in response to actions like touching, talking, or rubbing (**Figure 10**).

3.3. Fabric

3.3.1. Knitting

Florence is also known for its textile industry, producing both woven and non-woven textiles. We also collaborated with a local textile mill, and observed the production of these fabrics (**Figure 11**).

Figure 8. Thermochromic pigments were painted on ceramic surfaces: these patterns are responsive to differences in temperature, such as cold or heat.

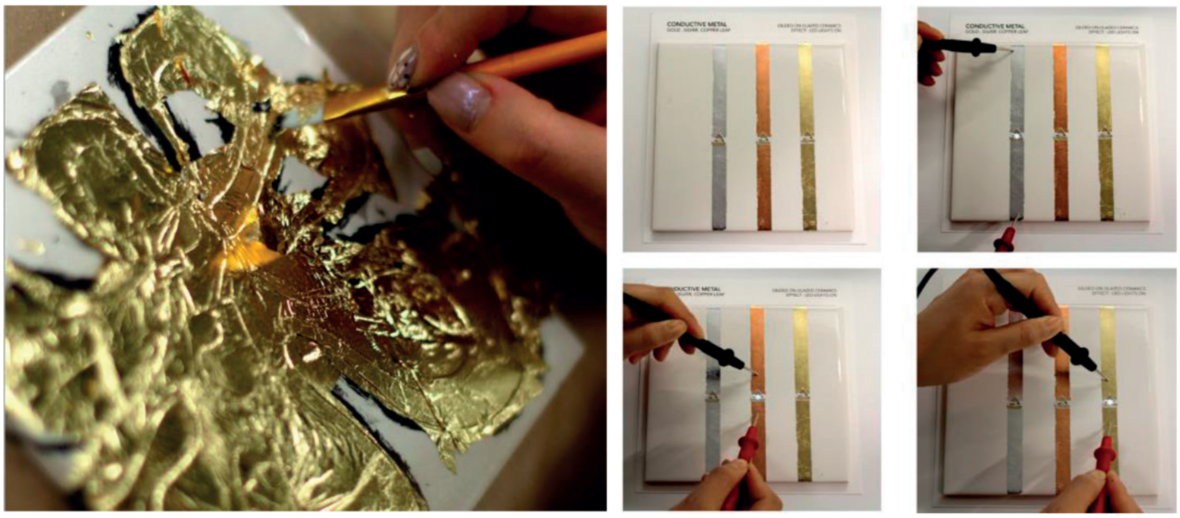

Figure 9. Metallic leaves (copper, silver, and gold) were applied to ceramic surfaces using gilding technique. Due to its conductivity, gilded patterns can become circuits to create interactivity.

Figure 10. Testing of adding simple LED light interactivity using gilded metallic circuits.

Figure 11. Left: textile mill near Florence that produces performative textiles. Middle: the woven textile inspired the potential integration of conductive fibers. Right: testing the idea of adding sensors to the conductive substrate for added interactivity and performance.

Using the sample of woven textile received from the mill, we started weaving very thin flexible wire to the fabric. A simple parallel circuit could be made with this conductive substrate, by adding a simple LED and a switch.

Next step in the exploration was to embed the conductivity to the textile itself during the production of the woven textile. Using a knitting machine, conductive yarn was knitted together with regular yarn to create striped patterns, which would become touch-sensitive areas when connected with a microcontroller. As shown in **Figure 12**, conductive fibers can be used both as decorative elements (visible) and as hidden substrates. In this exploration, upon touch of the conductive stripes, various sound tracks were played: producing an unexpected outcome from an everyday material like knitted textile.

3.3.2. Embroidering

Another technique that is often used on fabric is embroidery. Using conductive threads (such as stainless steel threads) to embroider alternative patterns on textiles can be used as visible decorations, that becomes part of the esthetics of the material itself.

3.4. Leather

3.4.1. Embroidering

Similar to the exploration with fabric, conductive fibers were embroidered/stitched on leather as visible patterns to create interactivity. These conductive stitches can be combined with

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Figure 12. Conductive fibers were knitted together with regular yarn to create conductive areas for touch interactivity to generate output, such as sound in this example.

regular stitches (on small leather goods such as wallets) to keep consistency in esthetics, yet provide interactivity through the use of actuators and sensors.

4. Discussion

4.1. Making materials reactive: substrates, pointers, and dynamic patterns

The samples production of hybrid materials allowed us to reflect on how technology and interactivity can be embedded into traditional materials. As a result, it emerged that hybrid interactive materials can have three different natures. Indeed, conductive and reactive materials can be embedded into traditional ones by craftsmen through artisanal processes in order to:

- Create *invisible conductive layers* that are hidden in materials but make them interactive and therefore able to respond to external stimuli, by being connected with sensors and actuators (e.g. LEDs). We call the conductive materials used in this way as “substrates”. Examples are conductive fibers knitted into hidden layers of fabric and becoming invisible. In this area, artisanal skills can be used to create high quality and performing hybrid materials, which at the same time have an esthetic quality that is the one of the original material, which hides its “smartness”. This can be achieved thanks to high expertise and knowledge of the material production process (e.g. fibers manipulation in fabrics or paper).

- Create *visible conductive elements*, which at the same time are noticeable, transform the static visual appearance of materials and make them interactive when connected to sensors and actuators. We call the conductive materials used in this way as “pointers”. Examples are metal leaves gilded on ceramics, conductive ink painted on ceramics or fabric, and conductive fibers embroidered in leather. Artisanal skills can help making pointers both esthetically pleasant and functional.

- Create *smart decorations*, which dynamically change the materials’ visual appearances according to external stimuli (light, temperature, and humidity). We call the reactive materials used in this way as “dynamic patterns”. Examples are interactive pigments painted on paper, tiles, or fabric. They do not need additional elements like sensors and actuators to transform the esthetics of the material, as they are interactive *per se*. They usually are visible on materials and can be used as decorations (**Figure 5**) but they can also be transparent and become visible only when a reaction to a stimulus occurs (**Figure 8** of transparent reactive pigment). Artisans' expertise can be leveraged to assure reliable painting processes and to provide final products with innovative esthetics.

Figure 13 shows how the conductive/smart materials we used in our experiments can be classified as substrates, pointers or dynamic patterns.

Substrates and *pointers* make materials conductive, therefore can be used in many different applications and can be coupled with any kind of sensors and actuators. Thanks to their properties, they can be used both to dynamically change the appearance of the material, creating new esthetic experiences (e.g. touching a conductive fabric turns on embedded LEDs), and to create functional interactions (e.g. rubbing a conductive fabric a signal is sent to my smartphone and a call to my boyfriend is initiated).

Dynamic patterns can be used only to change the appearance of the material they are coupled to, therefore they can be used to create dynamic *esthetic* experiences, where function is left aside. However, transforming materials' or products' esthetics in a dynamic way can have not only esthetic but also functional goals, as dynamic products [5] and ambient interfaces [10] demonstrate. Indeed, changes in the visual appearance of a product/surface can be used to communicate information to users (e.g. the temperature of a room, the presence of UV radiations, or the humidity level in the environment).

4.2. Potentials

Making traditional materials interactive and smart while at the same time maintaining their physical and sensory properties and manufacturing processes opens up new perspectives and possibilities.

As far as the artisanal world is concerned, such materials represent a way to transform and innovate craftsmanship while at the same time preserving its nature and values. Indeed, we

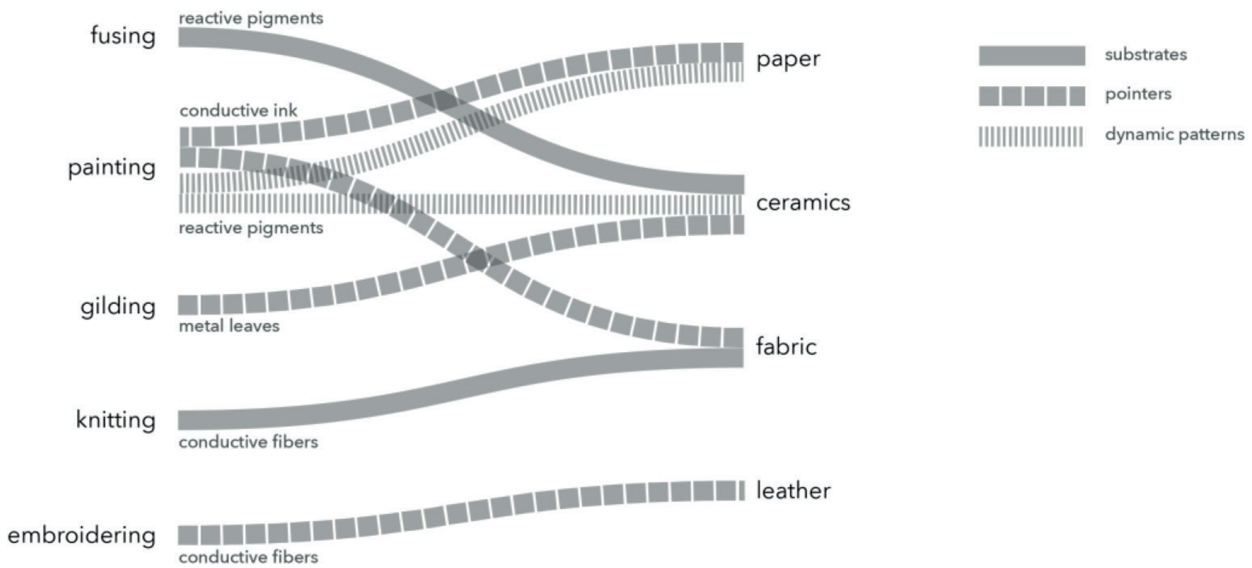

Figure 13. How conductive fibers, metal leaves, conductive ink, and reactive pigments are used as substrates, pointers, and dynamic patterns.

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explored how it is possible to use the traditional artisanal processes and gestures to embed electronics into paper, ceramics, leather, and fabric. This provides the possibility to use all the fascinating sets of manual and crafting activities to shape materials and objects that are smart and interactive. Instead of focusing on the DIY movement, this work explores how "smartness" can be embedded into matter and objects thanks to well-established processed performed by skilled and expert artisans. This approach is a middle way between the electronics industry, perceived as technical and cold, and the hobby-ist or DIY movements, where usually inexpert people produce single pieces, sometimes for fun or just as experiments. Through our exploration, we showed that there is a still unexplored area, that of artisanal industry, where well-established and traditional artisanal processes can be enriched by hybrid materials, towards the creation of high quality, manufactured materials or products realized in small series.

From the users' perspective, we can imagine completely new kinds of experiences that are enabled by these hybrid materials, where technology is made more familiar and contributes to the creation of new sets of interactions and experiences with well-known materials. Indeed, by seamlessly embedding interactivity in traditional materials, we can exploit the typical gestures users perform on such materials to shape new kinds of interactions.

In order to bring these hybrid materials into the processes of traditional artisans, new fabrication knowledge may be required. Is a new "artisanal" interaction design needed to push forward innovation in traditional craft products? In the subsequent collaboration with the artisans following this material exploration phase, we tried to address this issue by working closely both with the artisans and their young trainees, who tried to implement the interaction design approach in the traditional processes of artisans. As a first result, it emerged that this process is not always smooth and a balance between understanding traditional processes and embedding visible/invisible technology is needed to create new traditional materials with dynamic esthetics and interactive properties. However, this experiment was a first attempt to explore possible ways to reconcile craftsmanship and technology, by putting the user experience at the center.

5. Conclusions

We started from the analysis of traditional artisanal manufacturing processes and techniques, and identified a number of processes that could be used to generate hybrid, interactive materials. We proposed a framework to categorize these materials and to highlight their different possible uses in artisanal processes. By creating such framework, we intend to provide a tool to explore, with artisans and by artisans, new evolutions of their activities and to inspire their work.

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