New Materials = New Expressive Powers. 
Smart Material Interfaces and Arts, an Interactive Experience Made Possible Thanks to Smart Materials

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ABSTRACT
It is not easy for a growing artist to find his poetry. Smart materials could be an answer for those who are looking for new forms of art. Smart Material Interfaces (SMI) define a new interaction paradigm based on dynamic modifications of the innovative materials' properties. SMI can be applied in different domains and used for different purposes; functional, communicative and creative.

In this paper we focus on experimenting in the art and creative communication domain. In particular we describe the results of a workshop held with 15 students of the Fine Arts Academy in Venice who learned how to make and program SMI and took advantage of their new skills to design a variety of interesting creative artifacts.

Categories and Subject Descriptors
H.5.2 [User Interfaces]: Interaction styles, prototyping; J.5 [Computer Applications]: Arts and Humanities

General Terms
Design, Experimentation

Keywords
art, Arduino, DIY, maker, origami, programming, smart material interface

1. INTRODUCTION
From ancient times the artist has always been a highly specialized and skilled artisan. He made most of the tools that were necessary for his disciplines, such as: paint, pigments, canvas, finding the best marble and so forth. For modern artistic disciplines, which can be addressed under the label of interactive systems, the artist is only a user of methodologies and algorithms that have been conceived by highly skilled technicians. He often has no idea of how these artifacts works nor how they are made. By operating in these conditions, the artist’s work is limited to what the artifact (hardware or software) can do not allowing the full expression of his poetic vision. These artifacts usually were not created with that objective in mind.

With Ubiquitous Computing, the context of computing has shifted to the real world, embedding computation in everyday-life objects. Although this evolution often comes with the need for complex and costly technical infrastructures. While some artists, working in cooperation with the technicians, have taken advantage of these new opportunities (e.g., The dangling string [15], N. Jeremijenko, that materialized the data flux of a research centre), others could not. In most cases such a situation has just enlarged the dichotomy between the artists and the possibility to build the tools for the creative work.

The modern movement of makers focus on do-it-yourself (DIY) and often inexpensive implementations of interactive systems. This creates a suitable moment to bridge the gap between technology and creativity, giving the artists the opportunity to take control over the creative process from scratch. While promoting low-cost materials is an important feature that enables a lot of people to experiment with real systems, the most interesting feature of the maker movement is the pedagogical opportunity to learn how things work. The new classes of smart materials that are the focus of this work fit well into the DIY philosophy. We describe how we designed and conducted a workshop for a class of students of the Fine Arts Academy of Venice. The workshop focused on smart materials and techniques to create interaction on the Arts domain. The goal was to make artists aware of the potential of new technology, reducing the gap between technology and creativity and empowering their expressivity.

2. BRIEFLY ABOUT SMI
Before going ahead, we must give an idea of smart materials and Smart Material Interfaces (SMIs). A smart material is a material that can change a physical property in a controlled way. The property can stretch from color to transparency, from phase to stiffness or from conductivity to emitting light (and so forth). SMIs are interfaces that take advantage of these materials to promote a new way of interacting with the user. They give the possibility to convey a message in a physical way, for example deforming the shape of the interface to communicate to the user [8]. Several overviews have been written on interfaces made with smart materials. Among these, [7] shows how they are used
3. SMI AND ARTS

Some artists headed for the idea of using new materials as part of their artistic experience. Some are from a scientific background and applied their knowledge within an artistic shape. Kodama was the first to start to employ ferrofluid in art installations. She created several installations, among others: *Morpho Towers – Two Standing Spirals* consisting of two ferrofluid sculptures that move with the music [5]. Qi Jie gave several workshops, teaching interested people how to make use of SMA and paper [13], it is also possible to find more contributions from her and her group online, for example how to make a flapping origami crane [12]. An older work is the *Robotang* [4, 3] project by Jill Coffin, John Taylor, and Daniel Bauen in which the branches of a living tree are made to sway when someone walks by. Since the SMA wire is completely silent and hidden, the tree appears to be moving in a virtual breeze. In other cases smart materials are used just as a bonus to the usual artistic poetry of the artist. The photographer Fabian Oefner is a good example [9]. With his project *Millefiori*, video and pictures, he broke with his monochromatic tradition by throwing water colors into the mix of ferrofluid and brought in some luminosity and playfulness to his work. After him: soap bubbles, ferrofluid, food coloring, and magnets, a mix in a video called *Compressed 02* by Kim Pimmel [11]. The artist Afiq Omar has also been experimenting with ferrofluid and using the results to create frightening videos (*Ferienne* [10]). They look like mimicking lifeforms from another world. His experiments have seen him mix ferrofluids with items from the weekly shopping list: soap, alcohol and milk. The Brothers Mueller present an interactive wallpaper. Their aim is to bring wallpaper back to the foreground. *Viral (STD) Wallpaper* is a damask print with stylized graphic versions of sexually transmitted diseases. By touching the wallpaper, the visitors can trigger the viruses to “infect” the wall. The infection spreads thanks to Arduino (open hardware platform) connected sensors and thermochromic paint that allow the hidden pattern to appear [2]. In a similar concept for *Chair of Paradise*, the design of the chair is inspired by the mating behavior of a bird of paradise. This extravagant ritual which is rather humorous when performed by a bird, becomes nonsensical when it is done by a chair. The chair reacts to the proximity with sounds and pattern changes, thanks to thermochromic paint and Arduino [14].

4. EXPERIENCE DESCRIPTION

We organized a workshop at the Fine Arts Academy of Venice that lasted 5 sessions of about 8 hours each. The number of students was 14, formed into 7 groups. Most of them were aged between 22 and 25, but there were also one of 55 and one of 63. They were all students from the first or second year of the Master’s course, only one was from the third year of the Bachelor’s course. None of the students had any previous meaningful experience with imperative programming. Some of them had partial knowledge with Max/MSP. The general idea behind the workshop was to give the students different bricks of knowledge to allow them to build new concepts with as few constraints as possible.

**Materials used.** From the researchers, each group of students received a set of basic electronic components, accompanied by wires and an Arduino. The students were encouraged to get personalized tools and materials for their future projects. We used Flexinol for SMA actuation, a wire that contracts as a muscle. We used thermochromic paint both ready made and in pigments. For origami we used colored office paper. Each project was characterized by the use of different materials, but all of them included the smart materials and Arduino. We will describe the organization of the five days of the workshop, showing the main activity for each session.

**1st Day: SMI AND Origami.** At the beginning the students filled in the first questionnaire, about their personal profile, previous knowledge and interests in the workshop. We then opened the workshop with an overview of artistic interfaces made with smart materials and about SMI. The lesson lasted part of the morning. A few hours were dedicated to the creation origami models of various kinds and shapes. The lesson was a step-by-step tutorial. Each origami model was created altogether with the researcher. The origami models varied from basic shapes to more complex action models. The latter are origami models, such as talking fishes or barking dogs, that move if parts of the model are pulled. We then introduced Arduino and basic programming concepts, such as variables, conditional constructs and loops. At this point the students were divided into groups and several exercises were done.

**2nd Day: Arduino.** The second day started with the description of the Arduino I/O: the concept of pin and the methods to write and read from it. The rest of the session was dedicated for experimenting with Arduino, including hardware tests with LED and the other available components. We did experiments on how to control the properties of smart materials by using PWM (Pulse-Width Modulation). We then presented three possible themes: transposition of senses (synesthesia), object personality, picture feelings. They were designed to stimulate discussion and allowed a lot of freedom without putting many constraints on the creativity of the students. The students could choose one or more themes to fit. At the end of the day we asked the groups to bring in a conceptual proposal to the next session in the shape of a storyboard, that would contain the use of SMI in an art installation within the themes’ scope.
3rd Day: Thermochromic pigments. The day started with the students presenting their proposals, that were discussed and evaluated. We showed a short demo about SMA and thermochromic paint. The first was an actuated origami barking dog with a distance sensor as activation. The dog barked when the sensor detected an obstacle in its range. We also showed several examples of thermochromic paint applications. We then moved on and explained how to use and how to make the thermochromic paint from pigments. The students applied it to the origami models they had created. As last teaching of the day we showed the students how it was possible to connect Arduino to social networks (Twitter).

4th Day: Actuators. The students experimented with their first complete SMI. They applied a very small serpentine of resistive wire on the back of their painted origami models. They connected it to Arduino to power it up and make the origami model change color. Then, they learned how to create software switches for activating the SMI from Arduino. The students then built a small actuator with wood, NiTiNOL wires and ready made silicon springs. They connected it to Arduino with a MOSFET paper circuit and realized a light sensor based movement (to allow them to put in use all the notions learnt till now). At the end of the lesson we asked them to refine the proposal for the final project and to bring in anything they needed as external material to realize it. They also filled in the second questionnaire about the characteristics of their projects.

5th Day: Work in progress. In the last session, the students started to work on their projects. All the lesson was focused on the development of the key features for their project. Each of them had its own peculiarities and different problems to solve, from mechanical to software related. After the end of the workshop, several checks were made to supervise the development of the projects.

Projects. We have selected two projects (out of 7) in advanced state of development as a brief example.

#holy is the name of the installation (Fig.1) designed from a group that chose as theme object personality. The project is a picture-frame with an origami tessellation inside, designed to be placed in a public gallery. Here, the idea is to invite the visitors to reflect on the concept of holiness and share their reflections on the social networks. The visitor will be invited by a small panel, placed next to the frame, to think about holiness and to tweet their thoughts with the hashtag #holy. Using the authors’ words, “the cardiac muscle of the icon will contract as a sign of gratitude, for indicating that the concept of holiness has come back to life for a while in the hostile modern life”. From a technical point of view, the installation involves a number of triggers activated by an internet connection. NiTiNOL wires create the hidden silent motion from the back of the tessellation.

Da mano a mano (translated: from hand to hand) is the title of the installation (Fig.2) from a group that chose as theme picture feeling. It is a small square with hidden drawings and writing. The user will be invited to leave a mark on the opera by placing his palm on the square. As he does the action, the shape of his hand and a sign with written “I was here” will appear out the dark. The idea is that men want to leave a mark behind them to become immortal. It will be realized with thermo chromic paint, that becomes transparent when someone touches the installation showing up the hidden shapes.

5. DISCUSSION&CONCLUSIONS

The projects presented by the students are still in progress, but most of them are in an advanced state for what concerns the technical realization. Students are still working with our support for refining them, also from an aesthetical point of view, because we plan to organize an exhibition with their creations. While it is difficult to measure from a quantitative point of view the effects of the pedagogical path travelled so far, we may draw some conclusions about the students’ technical skills and the conceptual elaborations.

The initial questionnaire included a number of closed questions for capturing the students’ initial knowledge about smart materials and their application to the art domains, the
The answers show that students started from zero knowledge about all the themes that were presented in the workshop. During the experience they acquired new skills, such as making origami models, using previously unknown materials and components, soldering and programming. While at the beginning the students were guided, most of them demonstrated a good level of autonomy in using their new skills after the fifth day of the workshop, when they proposed their projects. We supported them with periodic checks in person or through videoconference conversations. The level of support never went beyond the suggestion of how to operate to solve a specific problem. All the practical operations were done by the students themselves. Most students described reasonable hypotheses for the technical realization. They went beyond the set of sensors and actuators that they could experiment directly in the previous days. Many groups demonstrated that they had acquired a methodology of work, visible since the selection of components to use in their projects, that applied to their realizations. Students introduced capacitive sensors for the input and traditional canvas as a support for thermochromic paintings, experimenting with new electrical circuits for composing their creations, seeking information on the web or asking teachers for advice. Students were not afraid of technology, tried new solutions for implementing their concepts. In each periodic check with the students we had a confirmation, for most groups, of a good level of autonomy in the technical development. In some cases the technical solution did not produce good results, so it was necessary to start again. But even the failures were useful, from a pedagogical point of view, for testing the limits of materials and components.

The second questionnaire captured their conceptual elaborations with a set of open questions. Students were invited to describe the features of their proposal, evidencing the relations with the planned delivery context and the inspiring conceptual sources if available. We noticed that the conceptual elaborations were made possible by the knowledge of the technical mechanisms explained and experimented with in the workshop. The single technical mechanisms were in many cases creatively composed in the conceptual definition of the students’ work, going beyond the schemes that had been using in the workshop, at the service of the expressivity of their work. According to our initial expectations, the students shifted from the role of users to the one of makers. The students imagined different social situations (e.g., the road, the art exhibition) in which to place their artifacts. These social situations, that required a physical or a virtual presence as in the case of the use of the Twitter social network, were often a primary component of the conceptual proposal. The students interpreted the relation between materiality and digitality in different modalities. Often the digital part of their proposal was hidden under the hood for the visitor, presenting the experience as a magic interaction between different materialities (the components of the installation and the user), as for the Da mano a mano installation. Of course these conceptual proposals would not have been possible without the acquired knowledge about the sensors and actuators of a digital system. In other cases students mixed the materiality of origami with the digital social world, imagining a sentient framed origami model that reacts with a pulse to the messages received from the associated Twitter account.

While we plan to collect more data with a third questionnaire about the outcomes of the students’ work, the discussions with them during the implementation phase evidenced some interesting results. Most students were satisfied with the knowledge acquired and some of them stated that they would consider the use of SMIs for their future artistic work. The planned art exhibition will be an additional occasion for disseminating the knowledge about SMIs and DIY, displaying the results in terms of creative solution, collecting the visitors’ opinions and stimulating the students to shift from the status of users to that one of makers.

6. REFERENCES


