Pigmento: a color experience to enrich learning awareness

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Abstract
Pigmento is a design driven research aimed to foster children awareness by playing with colors. Shaped as rounded table, it allows to mix primary and derivates colors, anytime with any amount. The basic principle is to move a granular opaque material over the surface which is videoprojected from the bottom. Meanwhile the material is physically constant, the color is perceived according to the user interaction. Moreover there is no need of training, because of the hands-on approach. Further exploration has shown the potential to design any color synthesis. It works in the realm of Computer Vision technology, using laptop, projector and camera. The configuration includes OpenFrameworks, OpenCV and OpenGL.

Author Keywords
Natural interface, color vision, color technology, learning, children

ACM Classification Keywords
Design, Algorithm, Experimentation, Human Factors

Introduction
The research started as Master Thesis in Interaction Design at IUAV University of Venice. The discipline's mission is to design the user behavior. The area of interest is to investigate an alternative way of learning,

especially on the enactive knowledge than any other [1]. As a matter of fact, it is encouraged to explore a medium using more senses and possibly learning by doing.
In the last decades more and more learning experiences are designed in museums, associations and outside the classical institutions. Some approaches of the kind, born in the recent past, are yet gaining some acknowledgement for their results. Some of them include Bruno Munari labs [2], Montessori Method [3] and "Learning through the Arts" [4]. A similar method is today applied in many museums workshops, especially for kids, in Guggenheim Venice [5].
Education in early age is essential to develop children's mind in any real environment. Learning through the arts is potentially effective approach towards this direction [6].

One of the main topics in children learning is about color, which is generally recognized as one of the most interdisciplinary of the kind. Since the age of two, kids already differentiate cold among warm colors. At three they start mixing colors by hands [7] Being able to change the matter by hands, users can quickly imagine the more and the wider around the topic. Color is a matter of study for many disciplines, from science to art. Specifically the design purpose is to bridge the gap between science and imagination.

Design

Some of the related experiences happen in museums and art spaces, especially in one day over the week. This may be called "the family day" or with a proper name according to the event. When it comes to play with colors, some activities are usually held around a table. This is the reason why the interface is physical. Further, it is interaction based. This does involve the user to show its potential.

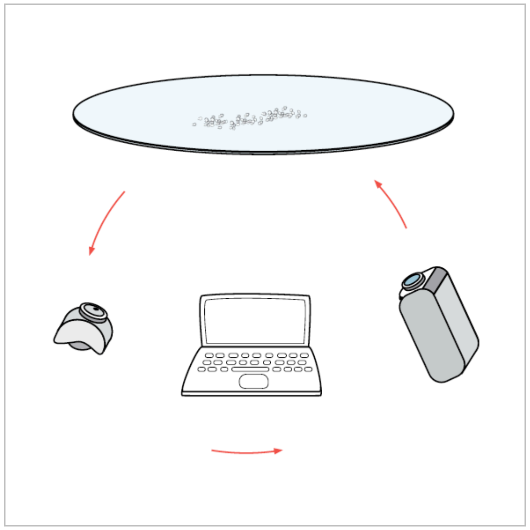

Figure 1. representation of the main components

Figure 2. look and feel

The more the users take part, the more they can achieve. Specifically, the rounded shape allows a better collaborative action. The diameter is around 1 meter and the height 70 cm.

The surface is split in two parts: lateral and central. The first is then composed of five parts, as the number of the primary colors designed in this experience: red, yellow, blue, white and black. The central one is potentially the sum of all lateral areas. The lateral sides are filled of primary colors, which are defined by physical separators. The experience starts by moving a granular amount of material from the lateral side to the center. This is always projected of a color light, which looks as a color from naïve eyes. The natural approach allows the users to move by hands any amount of their choice.

Because of several reasons as the morphological and cultural heritage, and practical ones, the adapted material is coarse salt. It responds with a wide gamut range when absorbing light. The variety of sizes reminds the grinding of colored minerals while making pigments [8]. Everyone takes his own "ingredient" to get a common result, which is always a process. The dimension is big enough to encourage the physical participation, so the user alone has to move the body to play with all colors. Of course more opportunities happen when playing together, up to five users each time.

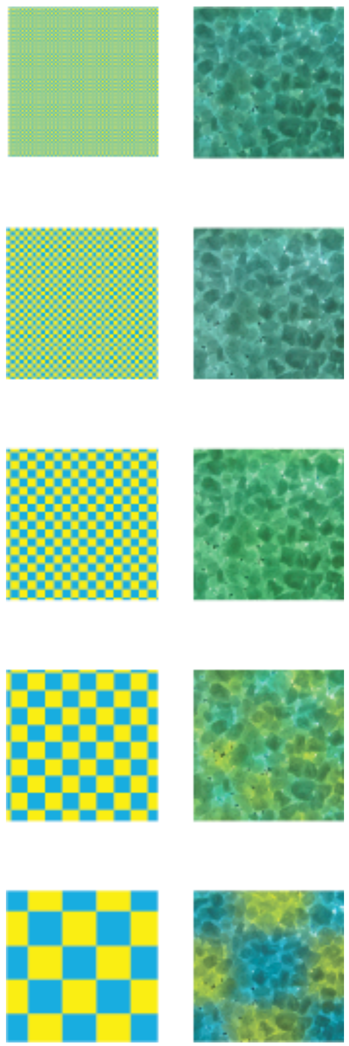

Figure 3. look and feel

Color Design

The color is the psychological response when light and matter meet each other.[9] There is a synthesis each time that more than one colors or lights share the spatial or temporal dimension, or either both. Usually when two or more lights overlap, there is a rise of the overall luminosity. For this reason this is called additive synthesis. On the opposite, when two or more colors overlap, the more wavelength are absorbed by the matter. As a result, the overall luminosity decreases. This is called subtractive synthesis.

In the previous two cases, it is always about overlapping and among the spatial synthesis types, there is a third one. This is called optical, because it happens mainly in human perception. Combining a matrix of different colors one close to each other, it may happen both of the specified synthesis types. In nature everything is made up of tiny points of color [10].

The main difference between color and colorants is about the inner structure. In the strict sense of the word, color is matter and therefore called pigment. Pigments are insoluble as opposed to colorants, which are always dissolved in a solvent. This is the main reason which leads to use the optical projection.

In practical terms, the spatial resolution is represented by texture or modules. The main factors are the observer distance from the surface and the dimension of the color units. In textures, the resolution is above the human perception. As a result, more colors are perceived as only one.
If the smallest units in modules look bigger, therefore it is possible to recognize both single elements and the "sum" of it according to the user distance [11]. Because of the morphological nuances of the salt, it is possible to get the subtractive color synthesis with lights.

Technical setup

Because of the required constant room light, the only possible site is indoor. The ceiling is covered by a dark cloth in order to get a better contrast between the whiteness of the salt with everything else. Inside the table, at the bottom center there is a Unibrain camera, Fire-i™ Digital Board and under the black color, which is not projected at all, there is the short throw videoprojector. In our case the Epson EB-460i. In order to keep the temperature constant, two funs 12cm diameter at a low round per minute (rpm) work all the time. The surface is made of temperate glass, with physical dividers and a stripe indicating the proper color for each lateral area. Meanwhile the laptop is outside the table, usually out of the participants view.

Development

From a computational point of view, each group of elements apparently merged together is called blob. It represent the logical unit we use in the computational phase, therefore, this term substitutes the word salt from now onwards.

The main computational challenges are about identifying and tracking all the blobs on the surface, and then to fill them according to the user interaction.

The technology used for the purpose is Openframeworks, defined as an open source C++ toolkit for creative coding [12], with the contribution of the libraries OpenCV and OpenGL. The process is made up of two main parts: initialization and loop.

Figure 4a. areas detection

Figure 4c. primary color filling

Figure 4b. blob tracking

Figure 4d. derivate color filling

The initialization role is to identify the areas, which are six: five lateral and one central. The latter is the sum of all the other areas. According to the room light, few changes are made on the threshold for the blob detection. From now the 3D dimensions of the salt are approximated to two.

At this stage, the central area is empty and each lateral area is filled with the proper primary color, according to the position of its centroid.

Right after, it starts the second part, called loop. All the blobs attributes are stored in a list (for each iteration), in order to make a comparison in real time *n* with the previous moment *n-1*.

In case of discrepancy between the two lists, it does mean something happened. Two scenarios are possible: a blob was not present in the n-1 list or a blob is not present in the n list. In the first case, the software can understand if the blob comes from a lateral area or if it is the result of a division of an existent blob and it will assign the right color. In the latter, again, the software will understand if the missing blob came back in a lateral area or it was merged with another blob.

In the latest case, the software takes the number of pixels for each merging blobs. Once calculated the percentage of each color, it will pass all to the information to the graphical processing unit (gpu), that will render the pixels thanks to a pseudo-random function.

User testing

The last prototype is a result coming from several iterations. The last version has been exhibited at Genoa Science Festival in 2011 Edition. Solely in Genoa, around 1000 people have had chance to play with, some of them several times. Because of groups up to 30 people in one hour, the experience is split in two parts: theory and practice. On the first, educators talk through the color, geographically and historically, from art to science. Then, 5 people each 10 minutes are allowed to freely play with the interface, without any first suggestion. A huge variety of people provided an endless feedback.

Some of the most common findings are about:

- personal discovery and surprise
- more willingness from younger children to explore compared to adults
- drawing of evidences coming from the personal user experience
- social conversation based on the action

deep questioning when the machine behavior was not acting as expected.

Results

The are two main results: user engagement and learning in user interaction and advancements in color technology. Along the only exhibition in Genoa, most children showed questioning and an attitude to stay longer than the usually available time. As seen in the previous prototype versions, it is possible to confirm the imagination process when manipulating granular material [13]. Apart the color, users usually draw real evidences, as objects, people and places.

In the latter, *the combination of technology and matter is able to go beyond the physical constraints*. The figure n. 3 shows that *juxtaposition doesn't not always convey in the additive synthesis, otherwise specified* [14]. A full sample records is in the thesis appendix, freely available online [15]. The design of the reiterated modules in OpenGL allows to possibly define any synthesis. In this scenario, it has been chosen the subtractive one because of the user interaction with physical matter, augmenting the previous experience with traditional colors.

Further research

There is a series of improvements imagined but realized, because of the complexity and lack of resources. Apart the technical sponsorship for devices, materials and consulting from Companies and Institutions, there were no financial means to progress in the research. The main areas of challenges not faced include:

- An automatic calibration of the settings
- A more feasible way to compensate any optical distortion
- A more precise set of computational algorithms in tracking, mixing and splitting
- A more advanced filling algorithm, which didn't provide the optical synthesis of green in the last prototype

Regarding the latter point, there are thoughts concerning the human ability to discern more shades of green comparing to any other hue. This could be a reason why there is a weaker synthesis in case of impurities.

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