Emotional Intelligence: Affective Computing in Architecture and Design

Behnaz Farahi

Abstract What if material interfaces could adapt physically to the user's emotional state in order to develop a new affective interaction? By using emotional computing technologies to track facial expressions, material interfaces can help to regulate emotions. They can serve either as a tool for intelligence augmentation or as a means of leveraging an emphatic relationship by developing an affective loop with users. This paper explores how color and shape-changing can be used as an interactive design tool to convey emotional information, and is illustrated by two projects, one at the intimate scale of fashion, and one at a more architectural scale. By engaging with design, art, psychology, computer and material science, this paper envisions a world where materials can detect the emotional responses of a user and reconfigure themselves in order to enter into a feedback loop with the user's affective state and influence social interaction.

Keywords Affective computing · Responsive materials · Active matter · Interactive design · Robotics

1 Introduction

Does matter "have" emotion? Can matter "recognize" emotion and "provoke" certain emotional responses in users? Can new materials be imbued with the right integration of sensing, actuation, and communication so as to serve as affective matter to detect and respond to emotions? (Fig. 1).

In the past many Western thinkers have viewed emotion as an obstacle to rational and intelligent thinking; there has been a large gap between rational and emotional perspectives. Conventionally, computers are considered as being rational and logical. They are also thought to be good at accomplishing certain cognitive tasks at which humans are not so good. Anything related to emotion would, therefore, need to be dismissed or simply not taken seriously by the scientific community [1].

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Fig. 1 Mesolite: An emotive display

In the past decade, this view has changed dramatically. At last, it has been widely accepted that emotional systems can also influence cognition. This means that everything we do has both a cognitive and affective component that assigns meaning as well as value. Emotions—whether positive or negative—can directly influence cognition and other behaviors including our perception, attention, motivation, and in general our decision-making capabilities. Advances in neuroscience and psychology about understating the role of emotion—such as the research by leading neuroscientist, Antonio Damasio—have led many computer scientists to attempt to create computers, which can understand emotions.[1]

2 Detecting Emotion: Emotional Computing

"Affective computing" is a term coined by Rosalind Picard in a paper at the computer science conference in 1995 [2]. However, the origins of this enquiry can be traced beyond this. For instance, in 1972 Manfred Clynes invented a machine called a "stenograph" for measuring emotions. In his experiments, subjects used touch and their finger pressure to express a sequence of emotions—anger, hate, grief, neutral, love, sex, joy, and reverence—while experiencing 25 min sequence cycles of music. He aimed to use his research as evidence that it is possible to "counter a negative emotional state by inducing a rather rapid shift into a positive one." In his book, Sentics: The Touch of the Emotions, he outlined his findings about "emotional perception and response at the intersection of music, art and mathematics" [3] and

[1]Note that there are many different theories for emotions borrowing from various disciplines including psychology, neuroscience, physiology, and cognitive science.

elaborated on the notion of "sentic" forms. "The emotional character is expressed by a specific subtle modulation of the motor action involved which corresponds precisely to the demands of the sentic state" [4].

"Affective computing" is now widely used to refer to the "computational modeling of emotion and implementations of autonomous agents capable of affective processing" [5]. Put simply, affective computing is about developing systems, which can recognize, interpret, and simulate human emotions through measuring physiological responses. In fact, studies have shown that the majority of affective communications take place non-verbally or para-linguistically through facial expressions, gestures, and vocal inflections [6, 7]. Thanks to sensor technologies various data from the user's physiological or neurological responses can be captured and processed. In a manner not dissimilar to how we understand each other emotions through modalities of various information, these systems can perceive cues for any emotions. For instance, computer vision sensors can be used to capture the bodily gestures and even facial expressions, while biometric sensors can directly measure physiological data such as skin temperature and galvanic resistance and help us to better understand our emotional state.

Although there is an ongoing debate as to whether emotions are socially and culturally constructed or universal,[2] in the 1960s American anthropologist Paul Ekman, aimed to show that certain types of emotions are not culturally specific and are in fact universal in all walks of life. As Evans puts it, "Our common emotional heritage binds humanity together, then, in a way that transcends cultural difference" [8]. Ekman called the following "basic emotions": joy, distress, anger, fear, surprise, and disgust. Through his research, he attempted to argue that the facial expressions associated with the basic emotions are innate and universal [9].

Universal emotions manifested in a physiological way through facial expressions, can be detected and recognized by computational systems. And if materials are enhanced with these computational systems, how might matter represent or simulate an emotional response accordingly? In other words, how can we map various emotions to various responses? Or, to put it another way, how might we use techniques for detecting facial expressions to control responsive behavior?

3 Provoking an Emotional Response

> …Emotion, as the word indicates, is about movement, about externalized behavior, about certain orchestrations of reactions to a given cause, within a given environment [10].

In 1944, Fritz Heider and Marianne Simmel conducted a very interesting experiment exploring how the brain assigns various emotional characteristics and constructs a story out of a series of events [11]. In their experiment, they showed participants

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[2]For instance, in her latest book, How Emotions Are Made, Lisa Feldman Barrett argues that emotions are socially and culturally contrasted.

a short simple animation and asked them to describe what they saw happening. What they discovered is that many people assigned certain characteristics, such as emotions, intentional movements, and goals, to simple shapes and their associated movements even though there is no evidence of any facial expression or even any indication of human representation.

In 1986, Valentino Braitenberg made another fascinating observation in his book, Vehicles: Experiments in Synthetic Psychology [12]. In his thought exercises, Braitenberg envisioned simple robots that could produce surprisingly complex—and seemingly cognitive—behaviors. Even though these vehicles are able to move around autonomously based on how their sensors and wheels are wired together, it appears that they have a form of agency that allows them to achieve a goal or even represent various characteristics such as being aggressive, explorative, passionate, and so on. For instance, a robot avoiding the source of light can represent emotion of "fear", not dissimilar to how a bug escapes from the light in order not to be caught.

Of course one of the big questions in all these observations is how to exploit the natural phenomenon of anthropomorphism—the process by which we attribute mental characteristics to animated objects. It is fair to argue that, by utilizing material movement or color change as an interaction design tool, it is possible to use these tools for emotional communication. Most of these material interfaces have been used/studied already for their visual and haptic communication properties, but not necessarily for emotional expression. However, this area of research is growing. As Strohmeier et al. note, "Recent explorations into shape changing interfaces have begun to explore how shapes might be used to output emotions" [13].

So, how could shape- and color-changing designs convey emotions and how might this development change the experience of design? How would the application of such development in wearables potentially benefit those who suffer from an incapacity to understand emotional cues from their environment? Or how might an architectural element benefit from engaging emotionally with the visitors? This paper uses two projects, which engage with the notion of emotional computing at various scales, in an attempt to answer these questions.

4 Facial Expression Tracking

Mark Weiser' notion of "ubiquitous computing" has already became a reality. We now live in a world where computational devices are embedded throughout the environment. The notion of smart environments and smart gadgets are becoming more and more part of the fabric of our lives, from Fitbit tracking the number of calories that we burn, to Apps tracking our sleeping patterns, to Nest thermostat, learning from the pattern of our behavior in buildings. It is time for computational systems to not only engage with quantitative aspect of our life but also to create an interface with our emotions.

Applications of facial expression tracking systems include

1. Studying the affective reaction of costumers for marketing purposes to understand their satisfaction about a certain product
2. Serving a customized media content for advertising purposes
3. Observing the mental health of patients for clinical psychology and healthcare
4. Monitoring facial responses for security purposes in airports.

For example, in the commercial world, the chocolate manufacturer, Hershey, has developed a dispenser in their retail outlets, which rewards you with a sample if you smile. The intention is to enhance the in-store experience and create a sales opportunity. Meanwhile, their competitor, Mendelez International, plays commercials based on an age and gender of the detected costumers [14]. Likewise, facial expression tracking has been implemented in the media and entertainment industry in order to create experiences such as FaceDance,[3] which allows people to control the movement of a virtual Michael Jackson through their facial muscle movement.

This paper argues that facial expression tracking can be embedded into the fabric of materials for a number of purposes:

1. The application of emotional computing into smart wearables could augment emotional intelligence. It could not only provide a better understanding of our emotional state in an objective way but also give us clues about our social settings.
2. The application of emotional computing into smart environments/objects could create a more empathic and engaging experience by establishing an affective loop with the user.

5 Opale: An Emotive Soft Robotic Garment

How might clothing sense aggression, and go into defensive mode accordingly?

This section describes the design strategy behind Opale, an emotive garment which can recognize and respond to the emotional expressions of people around it. The aim is to develop a soft robotic wearable fitted with an electro-mechanical system that controls the shape-changing behaviors mimicking the emotional expressions of onlookers (Fig. 2).

Human hair and animal fur are some of the most inspiring natural phenomena both in terms of their morphology as well as communication purposes during social interaction. Inspired by animal fur, Opale is composed of a forest of 52,000 fiber optics embedded in silicon which bristle when the wearer is under threat.

The intention behind the material development of this project was to control the location and orientation of hair-like elements so that they might respond to underlying forces not dissimilar to how hair stands up due to micromuscle contractions attached to hair follicles when we experience goosebumps or piloerection. These involuntary responses within the skin are due either to temperature changes or the experience

[3] Designed by filmmakers Ariel Schulman and Henry Joost and creative coders Aaron Meyers, Lauren McCarthy, and James George.

Fig. 2 Opale: An emotive soft robotic garment

of emotions such as fear, sexual arousal, and excitement.[4] To achieve this goal, a series of inflatable silicon pockets were incorporated beneath the fur-like skin in order to generate deformations in the texture and surface volume. The distribution of fibers on the surface was based on a study of the architecture of the human body. Data captured from an analysis of the surface curvature of the human body and the underlying contours of the muscles informed the location, density, and height of fiber distribution. The intention was to exaggerate the movement of underlying muscles by having the denser and longer fibers follow the contours of the curvature beneath (Figs. 3 and 4).

The inflatable behaviors were controlled using a custom-designed electrical board attached to an Adafruit Feather microcontroller (M0 with ATSAMD21G18 ARM Cortex M0 processor) capable of controlling an array of six low powered three-port medical solenoids (LHLA Series). This facilitated the computational control of air pressure and rapid inflation through the Arduino programming environment. As a result, each of the six pneumatic soft composites pockets were capable of providing dynamically controlled texture patterns that could vary in speed and frequency of change. For this, a miniature sized CO_2 capsule (16 grams, LeLand), a regulator (15 psi output, Beswick), and lithium polymer battery (3.7 V, 2000 mAh) were used (Figs. 5 and 6).

From the perspective of interactive design, this project looks closely at the dynamics of social interaction. We tend to respond to people around us through our unconscious facial expressions and bodily movements. When surrounded by smiling people, we often smile back. And when threatened, we often take on a

[4]The fabrication process for this project consisted of manually inserting 52,000 fiber optics into the laser cut mounting surface (1/4″ clear acrylic sheet). After placing all the fibers into the surface, the fibers were carefully moved to a bath of silicon. After 48 h, once the silicon was fully cured, the mounting surface was removed gently from the fiber landscape.

Fig. 3 Left: Placing fibers into the clear laser-cut acrylic sheet. Right: Data from surface curvature analysis of the human body informs the location, density, and the height of fibers

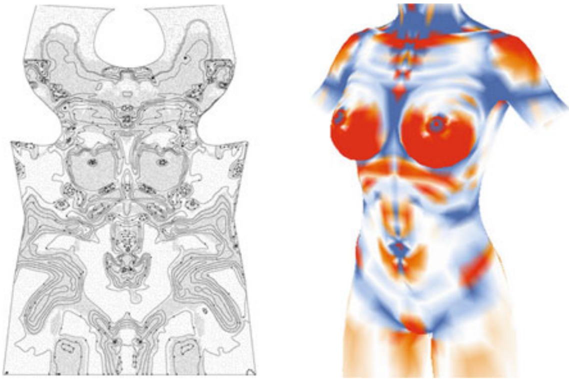


Fig. 4 Left: Placing fibers into the clear laser-cut acrylic sheet. Right: Data from surface curvature analysis of the human body informs the location, density, and the height of fibers

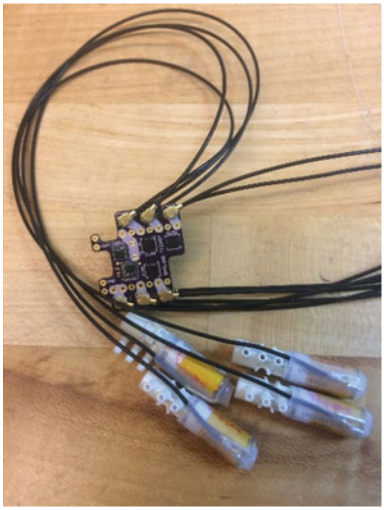


Fig. 5 Left: A pneumatic control circuit consisting of six three-port solenoids valves with coax cable connections. Right: 16 g CO_2 capsule and regulator (15 psi output)

Fig. 6 Left: A pneumatic control circuit consisting of six three-port solenoids valves with coax cable connections. Right: 16 g CO_2 capsule and regulator (15 psi output)

defensive stance. Through the logic of neuron mirroring, we mimic each other's emotional expressions. Likewise, animals use their skin, fur, and feathers as a means of communicating. Dogs, cats, and mice bristles their fur as a mechanism of defense or as a form of intimidation (Fig. 7). Darwin was the first to examine the emotional signals in humans and animals in his book, *The Expression of the Emotions in Man and Animals* (1872). He argued that the way that our hair stands on end when we are scared is a "leftover from a time when our ancestor were completely covered in fur" and its role was to make them look bigger and more intimidating [15].

The challenge, then, is to develop clothing that can likewise express emotions. For example, might it be possible for clothing to sense aggression, and go into defensive mode accordingly?

The challenge was to explore whether emotions expressed in our social interactions could be represented in a non-verbal way through the motion of a garment. Thus, the garment would become an expressive tool or apparatus that empathizes with the

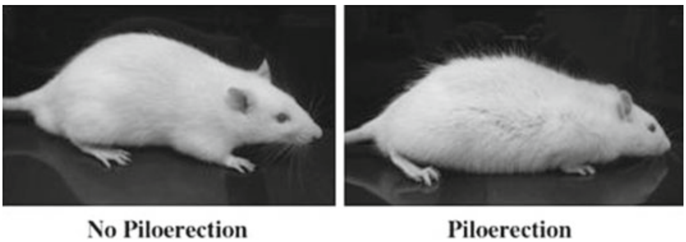


Fig. 7 Piloerection in mice accessed from https://www.nature.com/articles/1300989

onlookers. For this purpose, this dress is equipped with a facial tracking camera that could detect a range of facial expressions on the onlooker's face: happiness, sadness, surprise, anger, and neutral. Each emotion detected was sent to a microcontroller (Teensy 3.2) capable of activating the solenoids to generate various patterns and inflation speeds in each air pocket (Fig. 8).

For example, if the dress were to detect an expression of "surprise" in an onlooker's face, the wearer's shoulder area would start to inflate. Or when an onlooker expresses "anger", the wearer's shoulder and chest would start to inflate and deflate with a frantic, aggressive motion. When people around start to smile and demonstrate "happiness" the dress would ripple subtly from top to bottom (Figs. 9 and 10).

Although the current application of emotional computing and soft robotics for wearables still has limitations, it opens up exciting opportunities for shape-changing clothing in the future for both communication and healthcare purposes. Not only does the smart garment promise to become part of the apparatus of human intelligence but

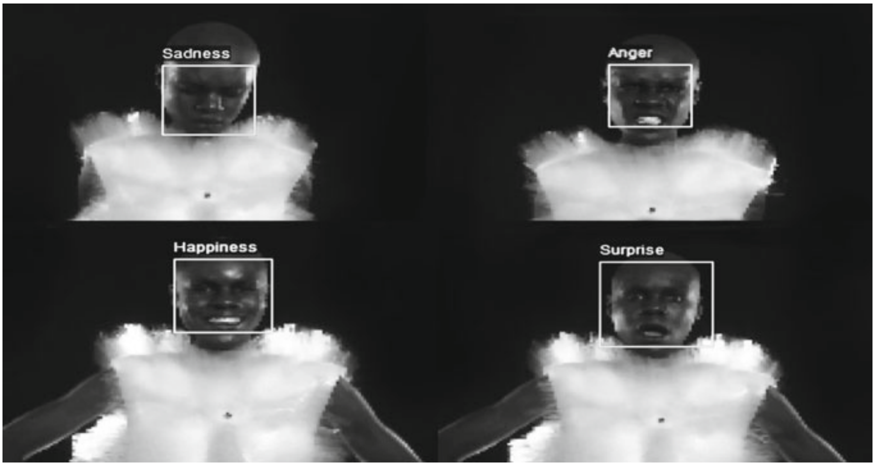


Fig. 8 Facial tracking camera embedded into the silicon dress, and can detect onlooker's facial expressions

Fig. 9 The dress is responding to the onlooker's emotions

Fig. 10 The dress is responding to the onlooker's emotions

it can also benefit many people with autism who have difficulties recognizing facial expressions. People with autism might be paying attention to what you are saying but be unable to tell if you are happy, sad, or angry. As a result, their responses might not match the desired expectation, leading to isolation and rejection by others. Such a system can help them blend more easily with others and over time learn appropriate responses.

6 Mesolite: An Emotive Display

How can we create an engaging emotional experience for costumers by design of an interactive display? How can the life-like quality be told through materials, dynamic behavior, and color transformation? How can persona and character be used as a tool for interaction design?

Mesolite is an emotive display commissioned by Adidas designed to showcase the 2020 Predator concept shoe, and offer retail and other consumer experiences. The aim is to explore how computer vision and facial tracking technology can be implemented in the design of a display in order to influence patterns of social interaction and maximize the engagement with the viewers by giving animal-like qualities to the designed display object (Fig. 11).

Inspired by the form of a soccer ball, the Mesolite sphere consists of 31 hexagonal and pentagonal modules CNC milled out of black acrylic. The sphere is equipped with a facial tracking camera and has an irregular opening in which their latest soccer shoe is showcased.[5] Inspired by the natural formation of Mesolite crystal, the sphere is mounted with 1,800 acrylic tubes (1/4″ diameter)—varying in length—lit up with various lighting effects to convey the speed and movement of the player and soccer ball on the field (Figs. 12 and 13).

[5]Each hexagon and pentagon was milled (using three- and five-axis milling tool) using 1″ thick black acrylic sheet with a designed indent allowing each module to be connected to another module with two sets of screws on every edge. The attempt was to have a modular system both for ease of assembly as well as fabrication cost. Each module has about 70 unique angled holes into which acrylic tubes are mounted.

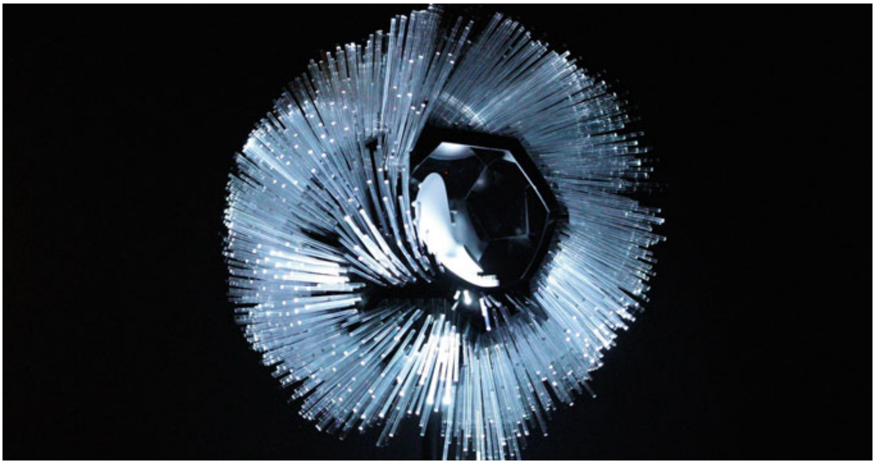
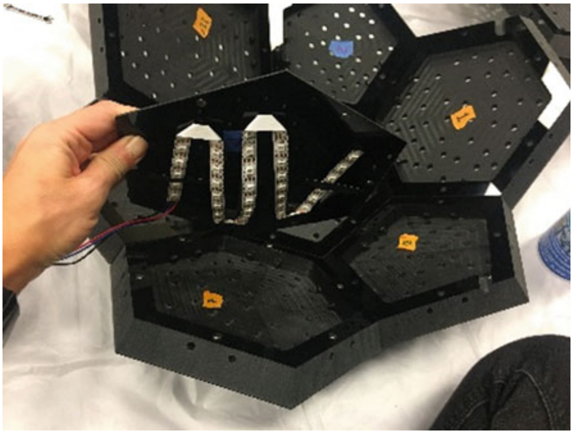


Fig. 11 Mesolite, an interactive display showcasing the latest soccer shoe, responds to the excitement of the visitors

Fig. 12 Left: five-axis CNC milling of side holes for modules inter-connections. Right: Assembly of seven modules, showing one module with a dedicated LED panel

Fig. 13 Left: five-axis CNC milling of side holes for modules inter-connections. Right: Assembly of seven modules, showing one module with a dedicated LED panel



The piece has a certain magic and wonder to it, similar to how fireflies emit lights in nature. Embedded with 1000 individually addressable R, G, B LED pixels, the tips of acrylic tubes illuminate creating a mesmerizing dance of light. For this purpose, from inside, every hexagon and pentagon has a dedicated 1/8″ panel, which can be attached with sets of small magnets and which house the LED pixels. Each panel connects with a female-male latching connector to the neighboring module. All the wires that connect the LEDs meet each at the bottom of the sphere where they connect to the dedicated microcontrollers. Inside the sphere, there is a platform with an organic-like landscape of fiber optics (similar to Opale) equipped with 300 LED pixels and an aluminum shaft connected to a stepper motor in the middle. The product—the Adidas Predator 2020 shoe—is mounted on the shaft above a landscape of fiber optics, creating an organic interaction between the body of the shoe and the fiber optic landscape.

The Mesolite display has an "eye", a facial tracking camera which can detect the facial expressions of up to 35 visitors and the locations of their heads relative to the opening of the sphere. When a face is detected, Mesolite comes out of "dream mode" and acknowledges the viewer's presence. "Dream mode" refers to when the shoe is not moving, and when the LED patterns of light have a subtle movement with a white glimmering light effect. Once the face of the visitor is detected the Mesolite comes alive, acknowledging the presence of the viewer by generating a red ripple of light which goes across the surface from the opening to the back of sphere as though it is welcoming the visitor's presence. The shoe inside also comes alive by tracking the head of the visitor thereby creating an intimate engagement with the viewer. For this purpose, the $<x, y>$ value related to the head location of the viewers captured from the camera is mapped to the rotational position of the shoe, giving the illusion of the shoe facing the viewers. In this way, Mesolite is given a form of attention directionality. If there are multiple people in front of Mesolite, the camera computes the values of the detected faces all together, and the shoes start looking at multiple faces as though it is trying to capture the attention of multiple people. Once a person has the attention of Mesolite, she has to try to keep it by getting closer. If not, the shoe starts switching its attention to as many faces as detected in front of the opening (Figs. 14 and 15).

The more the viewer engages, the more Mesolite comes to life. When the viewers express surprise, the red lighting starts to ripple in and out with deep breath-like rhythms. When the views smile and express happiness, Mesolite will share the happiness by having the shoe spin around and the red light starts to flash rapidly a few times as though it is also excited and happy! (Figs. 16 and 17).

The computing system for the piece includes a central brain (Raspberry pi) and four microcontrollers which receive information from it. The task of the Pi is to process data from and send data to microcontrollers that interact with the physical world.[6] As such, Pi contains the main application loop, which is orchestrated to

[6]The brain of the pi is written in python3 with some high-performance cython code reserved for the LED animations, while the microcontroller code is written in a subset of C++, using standard

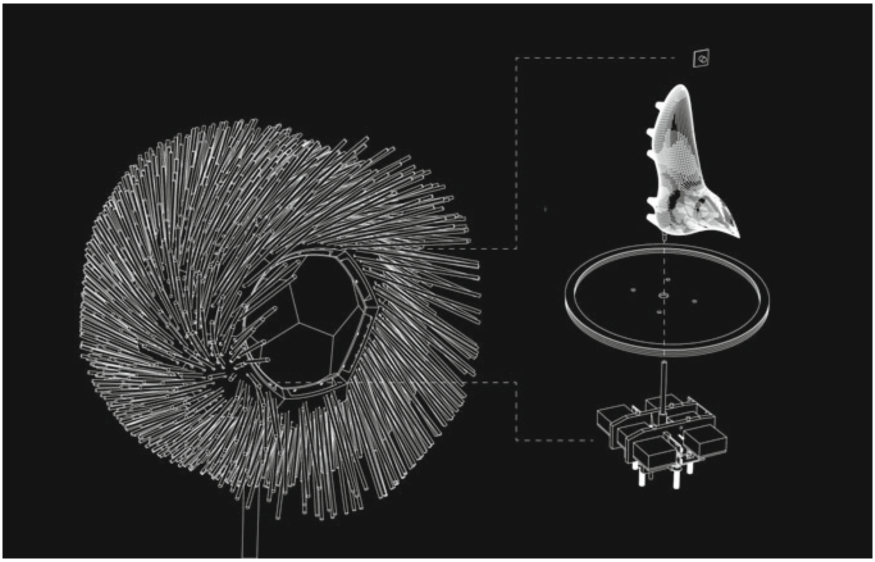


Fig. 14 Diagram of placement of each element in the sphere. On the right-hand side from top to bottom: Camera, Predator shoe, Platform with embedded LED and fiber optics, Computational brain

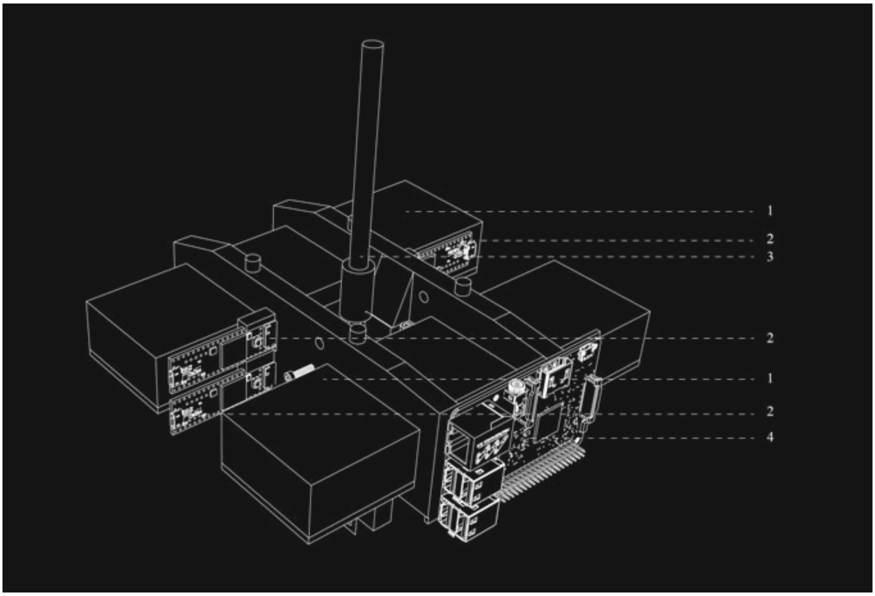


Fig. 15 Computational brain includes (1) Two power supplies (40 A, 5 V), (2) Three microcontrollers (Teensy 3.6), (3) Motor (Mechaduino Controller), and (4) Raspberry Pi

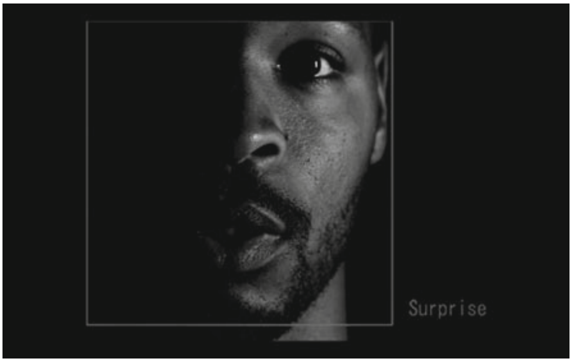


Fig. 16 The face location and emotional facial expressions of the viewer including surprise and happiness can be detected. Mosilte comes alive when a face is detected

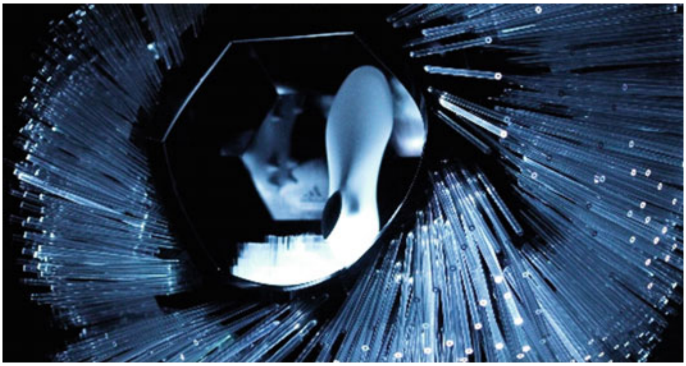


Fig. 17 The face location and emotional facial expressions of the viewer including surprise and happiness can be detected. Mosilte comes alive when a face is detected

run approximately 30 times a second, communicating with the connected microcontrollers to obtain camera data and drive the motor and LEDs. One of the challenges in the programming of the lighting system for this piece was to map the irregular structure of LED pixels to detect the exact location of each pixel with their dedicated ID in the 3D Vector space of the sphere (Fig. 15). To achieve this, we exported the coordinates of each point from the 3D file and stored them as a text file on the Pi. Prior to starting the loop, Pi parses the files related to the coordinate system of the LEDs to obtain the $<x, y, z>$ coordinates of each individual R, G, B LED unit. Three Teensy 3.6 microcontrollers were used, two of them attached to LED pixels and one attached to the camera. A Mechduino motor with its dedicated microcontroller was used to control the shoe movements, which required the development of our

Ardunio and Teensyduino libraries. The code for each can be compiled and deployed using the Arduino IDE (v 1.8.5).

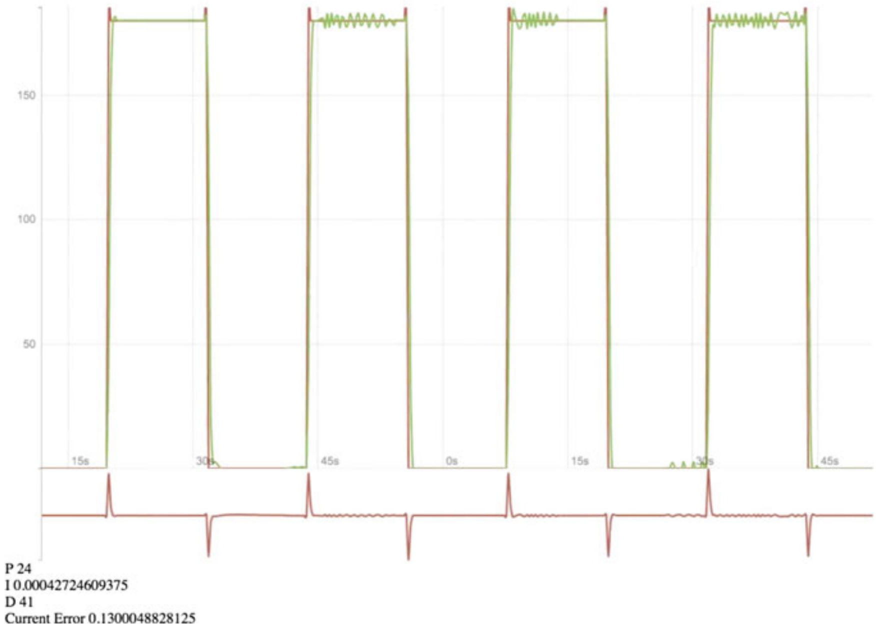
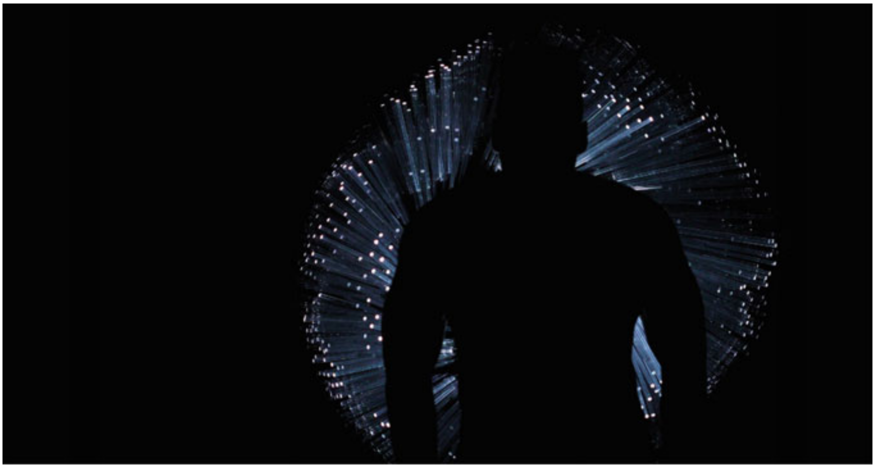


Fig. 18 Custom designed of visual interface for calibration of PID of the motor

own customized software to calibrate the PID for the motor[7] (Fig. 18). This was an essential step in understanding the motor torque, position, and acceleration, which was the key factor in designing the behavior.

The scope and application of this project suggests numerous design opportunities for the world of architecture and product design. What is clear is that in designing smart/robotic objects with life-like behaviors, these artifacts may deliberately exploit the divergence between the object's characteristics and preference and the human frame of reference. Anthropomorphism in this context refers to the emergence of interaction between a user and the robotic environment. According to Epley et al., this includes emotional states, motivations, and intentions ascribed by the user to the robot [16]. However, the task of expressing various emotions via shape-changing interfaces, as also noted by Strohmeier et al., is a significant design challenge which requires interdisciplinary approach uniting design, material science engineering, computer science, and HCI. Nonetheless, it opens up radically new opportunities for addressing psychosocial issues.

[7]A proportional–integral–derivative controller (PID controller) is a control feedback loop mechanism mostly used for industrial control systems. We have written our own software visualizer for PID controller which will be soon released in GitHub open source platform.



7 Conclusion and Future Work

This paper has sought to illustrate how materials augmented with computational tools can serve as an emotional interface. In this process two challenges have been addressed; one is how to detect emotions from the user and the other is how to provoke a certain emotional response in the user through the implementation of dynamic behaviors such as color and shape changes. So, in terms of the first challenge, the goal is to detect the viewer's emotion using a computer vision system and to store the information in the material. In terms of the second challenge, the material then responds physically to the detected emotion in order to establish an affective loop with users. The intention is to explore how shape- and color-changing interfaces might be used in the future to express and simulate various emotions through non-human representation. These material interfaces could be a very effective tool for the communication of emotions.

This paper has presented the design process behind two projects: Opale, an emotive soft robotic dress and Mesolite, an emotive display. The work described here serves as a proof of concept for the application of emotional computing in design which can be used as a tool for emotional regulation either to augment emotional intelligence (e.g., with a smart garment) or to develop an emotional bond by developing an affective loop with the users (e.g., with a smart object display).

The intention has been to demonstrate that despite our anxieties about smart environments and technologies in general, there is potential for empathy where these objects can become companions and co-exist with us and not against us. Moreover, while the capacity of computer vision to recognize different facial expressions has been exploited by many commercial and advertising purposes, the integration of such a system into clothing or architectural installation is a new venture which could open up novel opportunities for the world of design, HCI and architecture.

References

1. Picard, R.W. (2015). *The promise of affective computing in the oxford handbook of affective computing*. Edited by Rafael Calvo, Sidney D'Mello, Jonathan Gratch, and Arvid Kappas, Oxford University Press, Oxford.
2. Picard, R.W. (1995). *Affective computing*. MIT Media Laboratory; Perceptual Computing; Section Technical Report No. 321.
3. Popova, M. (2013). Sentics: Emotional healing through music and touch. Retrieved from https://www.brainpickings.org/2011/09/05/manfred-clynes-sentics/, also Clynes lecture on Sentic Cycles https://www.youtube.com/watch?v=quIcl5UG1z4.
4. Clynes, M. (1989). *Sentics: The touch of the emotions*. Revised edition. Bridport, Dorset: Prism Pr Ltd.
5. Scherer, K.R. (2010) Emotion and emotional competence: Conceptual and theoretical issues for modeling agents. In K. R. Scherer, T. Banziger, & E. Roesch (Eds.), *A blueprint for affective computing: A sourcebook and manual* (1st ed.). Oxford , New York: Oxford University Press.
6. Mehrabian, A. (1971). *Silent Messages*. Belmont, California: Wadsworth.
7. Picard, R.W. (1998). Towards agents that recognize emotion. In: *IMAGINA, Actes proceedings* (pp. 153–155). Monaco.
8. Evans, D. (2003). *Emotion: A very short introduction*. ILL edition. Oxford , New York: Oxford University Press.
9. Ekman, P., & Lazarus, R. S. (1980). *The face of man: Expressions of universal emotions in a New Guinea village*. New York: Garland STPM Press.
10. Damasio, A. (2000). *The feeling of what happens: Body and emotion in the making of consciousness* (1st ed.). San Diego, CA: Mariner Books.
11. Heider, F., & Simmel, M. (1944). An Experimental study of apparent behavior. *The American Journal of Psychology, 57*(2), 243. https://doi.org/10.2307/1416950.
12. Braitenberg, V. (1986). *Vehicles: Experiments in synthetic psychology*. Reprint edition. Cambridge, Mass.: A Bradford Book.
13. Strohmeier, P., Carrascal, J.P., Cheng, B., Meban, M., & Vertegaal, R. (2016). An evaluation of shape changes for conveying emotions 2016. In CHI 2016 *Proceedings of the 2016 CHI conference on human factors in computing systems* (pp. 3781–3792).
14. Nieburg, O. (2015). Smile for candy: Hershey eyes-in store excitement with facial recognition sampler. Retrieved from https://www.confectionerynews.com/Article/2015/07/31/Hershey-Smile-Sample-Facial-recognition-to-dispense-chocolate?utm_source=copyright&utm_medium=OnSite&utm_campaign=copyright.
15. Darwin, C. (1983). *The expression of emotions in man and animals*. London ; Dover, N.H.: Pinter Pub Ltd.
16. Epley, N., Waytz, A., Akalis, S., & Cacioppo, J.T. (2008). When we need a human: Motivational determinants of anthropomorphism. *Social Cognition, 26*(2), 143–155.