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Augmented Membranes

Design Explorations into Responsive Materials

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Abstract In this short paper, we present several design explorations of our on going design research on responsive skins: "Morphosis", "Life Speculatrix" and "Nausea Transformer" [1] [2] [4], are working prototypes that physically respond to local and global external stimuli (movement, light and sound) interacting spatially and temporally with the environment and their inhabitants. The fundamental hypothesis is to create architectural systems as evolving materials constantly being designed and re-designed through its inhabitation. All the three projects presented have responsive membranes controlled by genetic algorithms reconfiguring its behaviours according to different stimuli and learning how to adapt themselves continually to the evolutionary properties of the environment, thus becoming "*Situated Living Pieces*". The dynamic of the materials in the three prototypes is produced by dozens of actuators made by Shape Memory Alloys (SMAs) and LED's which react in real time to change the behaviour of the membranes.

Keywords Evolutionary design, Kinetic systems, Responsive environments, HCI.

1 Introduction

Our research, borrows its design logic from ubiquitous electronic technology, artificial life, robotics, and human computer interaction (HCI) models as integral components of the design system. Its objectives are to explore the potential of architecture to communicate, respond and perform for its inhabitants. We aim at developing affordable artifacts that combines architecture in form and function; and propose a selected mix of technologies as a way to in fact augment the physical capabilities of architecture, by sensing the environment and responding to stimulus and analog inputs, and by evolving and achieving the symbiotic behavior, we encounter on the natural environment.

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2 Concept Design of the Membranes

Beginning with the premise that digital technology and kinetic structures should be implanted in the physical materials of architecture, we have first developed a prototype interface titled *Morphosis*, a reconfigurable and visual system, based in our previous work [1], and inspired by the manner in which an organism, or any of its parts, evolve and change form in a short lapse of time, triggered by some combination of external stimuli in the ever changing surrounding environment. The *Morphosis* prototype [2] (Figure 2), was designed as a model to be suitable for execution of a responsive architecture material and to enable the development of transformable architectural surfaces. Also, by developing Morphosis we wanted to investigate how the learning qualities of a material could be used to improve communication between buildings and its inhabitants. We then continued building upon this experiment to create other variations with the same design concept. The several prototypes' behaviours are the result of complex system composed by sensors, microphones, web cams, shape memory alloys actuators, LED'S and a Genetic Algorithm (GA) component.

2.1. Technical Description

The main sensory unit is a web cam and a video analyzing program (C++) that determines the empathy or repulsion regarding the current skin behavior by noticing at any given time how close the viewers get to the wall. This is actually the Genetic Algorithm fitness function: how bright is the picture captured by the camera. By placing the camera looking down at an angle from the top of the wall, when a viewer comes into the field of view the images gets brighter and the fitness increases.

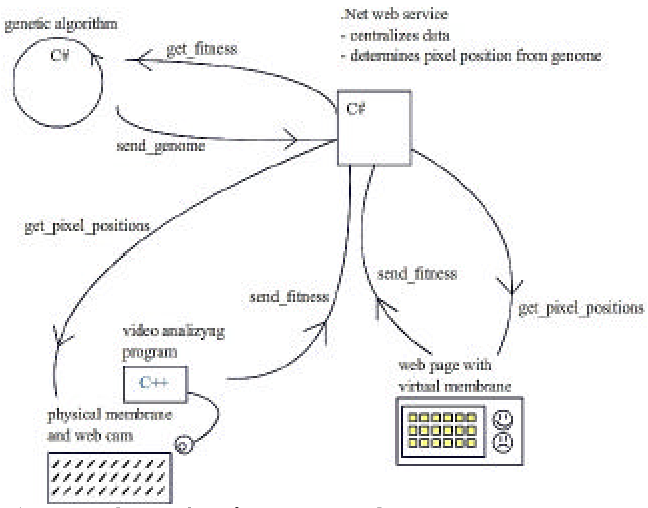

Fig 1 Membranes´s software system logic.

The viewers connected to the internet have a virtual wall representation (Flash) and two buttons for empathy ☺) and repulsion (☹), the clicking of each of the buttons constitutes also the fitness function (See Figure 1).

2.2. Machine Learning Feature

A GA involves a "genotype", this is the "internally coded, inheritable information" carried by all living organisms. It is a string of code specifying a "phenotype" which is the "outward, physical manifestation" of the organism.

In our experiments, our "phenotype" is the shape of the membrane, the sound responses and the behavior of the actuactors and LED's. The input actions of the users and the environment are inputs for the genetic variations. Four input devices inform the computer of the status of the surrounding environment: a webcam, a vibration sensor, a proximity sensor and a light sensor. These sensors are unobtrusively included in the wall and "feel" the environment informing the wall:

- Whether loud music is playing or someone is walking around (vibration sensor).

- If there is a rapid change in the ambient light levels (light sensor – web camera).

- If someone approaches the wall in a touching distance (web camera).

These inputs change the behavior of the membranes in shape, trigger sound, motion and light and can create random patterns on the surface, making the surface a responsive part of space, a lighting element, a functional architectural element and a performance piece.

The membranes start its learning process by responding to "empathy" or "repulsion" from the people around it (fitness). The environment feeds are inputs for the genetic variations. These inputs change the sound response behavior of the membrane, change its shape, and trigger motion and light, making the wall a performance piece. A wide range of possible "phenotypes" can be generated, and are evaluated for their "fitness" based on some formally specified criteria. Fitness is the relative probability of survival and reproduction for a genotype.

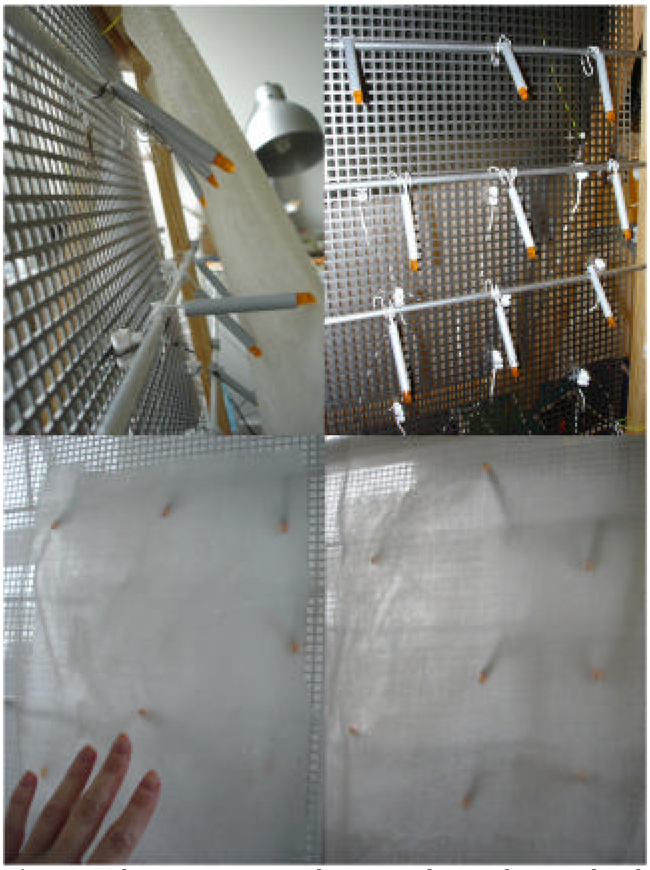

Fig 2 Morphosis prototype with its SMA levers above and with membrane below. This prototype was produced by the author in November 2006.

The membrane is always aware of its own shape at any given moment because the data is store centrally: the genome and each membrane pixel position; so when a fitness input is given (via web cam or flash web page), the genetic algorithm knows the current behavior being exhibited by the membrane and thus knows how to correctly classify it. For each generation (GA generation) each genome is tested (by displaying the phenotype defined in the genome at the membrane) and evaluated (by reading the fitness inputs); at the end of each generation the best genomes are selected and a new set of genomes is created (the next generation), this process is repeated endlessly adapting the membrane constantly.

The genomes and corresponding phenotypes:

gene behavior (phenotype)

locs

[0][1][2][3][4]

- 0 - if =1 then cols active left to right
- 1 - if =1 then cols active right to left
- 2 - if =1 then rows active bottom to top
- 3 - if =1 then rows active top to bottom
- 4 - if =1 then pixels are randomly activated

The wall begins, by running a random set of behaviours (raising and lowering levers to form patterns, and producing arbitrary sounds, taken from a reduced set of samples), and will try to adapt its effect sequences to get the maximum "empathy" responses. We will observe the "evolution" of this piece according to different stimuli and how it learns to adapt itself continually to the evolutionary properties of the environment.

3 "Life Speculatrix"

"Life Speculatrix" takes inspiration on Grey Walter's "Machina Speculatrix", three wheeled, turtle like, mobile robotic vehicles built between 1948 and 1949. Even with a simple design, Grey demonstrated that his turtles exhibited complex behaviours. He called his turtles "Machina Speculatrix" after their speculative tendency to explore their environment. Looking at Situationism [3], as an inspiration for alternative forms of HCI design with this project we argue that a HCI conceptual framework has to cross the phenomenological environmental matrix with the complexity of human input in order to create a truly living interactive experience and not just a detached interactive art device. The Situationists developed tactics to support questioning of the consumer static spectacle, such as the dérive, a series of random drifting walks through the physical space of the city. The "*dérive*" was taken up by the Situationists as a method for exploring psychogeography, which the group employed in studying the interplay between localized ambiences and the human psyche. With our experiment we propose a "virtual drifting", created by different digital inputs from around the globe. Participants here approach the environment outside of a goal-oriented frame, aiming to experience a new social, ambiences or moods that will affect a physical wall in an evolutionary fashion. All the necessary and sufficient conditions are therefore present for a "hidden dimension" to be added to a phenomenology and a poetics of visual space.

"Life Speculatrix" (Figure 2) is a kinetic evolutionary physical skin based on digital environmental feedback retrieved through the webspace. RSS/Atom Environmental feeds, like pollution levels, climate features, sound, from around the world will affect its performance continually interacting spatially and temporally with the environment and their inhabitants. The fundamental idea is to create an online project as a living, evolving tangible experience.

There is no explicit weighting of local versus remote input (fitness input): the local fitness input (web cam near the membrane) is sent every x seconds (6 seconds), the remote input is sent whenever a user clicks empathy (☺) or repulsion (☹). The RSS environmental feeds are stored to allow analysis of selected phenotypes compared to the environmental feeds gathered at the selection time; the purpose is to determine if there is any relation between the two (phenotype and environmental conditions). At a later stage this approach may be used to fine tune the membrane according to current environmental conditions favoring some genes as determined by historical data (to speed the adaptation process).

We will observe the "evolution" of this piece according to different stimuli, give it our feedback and observe how it learns to adapt itself continually to the evolutionary properties of the local and global environment, thus becoming a universal situated living piece.

Fig 2 "Life Speculatrix" prototype changing the membrane's shape according to RSS pollution feeds. This prototype was produced by the author in January 2007.

4 "Nausea Transformer"

The word "noise" comes from the Latin word nausea meaning "seasickness", or from a derivative (perhaps Latin noxia) of Latin noceo = "I do harm", referring originally to nuisance noise. Generally all non-musical sounds are considered to be noise. Noise is a complex concept and source material to deal with; it is an invisible architectural element with an undefined aesthetics. It deeply affects people and yet people feel very powerless to interact with or control it. The fundamental idea is to turn noise into a reprocessed living, evolving and tangible experience, by interacting spatially and temporally with the environment and its observers. Our purpose is to raise people's awareness to sound, in all its forms: speech, non-speech sound (sound pollution sources) or natural sound, and treat it like data with a corporeal dimension. We aspire to convey an embodiment to an often neglected "hidden dimension", by adding it to a phenomenology and a poetics of visual space. Building up on our research in interactive membranes [1] [2], we introduce *"Nausea Transformer":* a sound reprocessed machine that unexpectedly can create pleasant behaviours by recycling noise into pleasant sound, therefore promoting new interactive experiences to a nearby audience.

Fig 3 "Nausea Transformer" actuators changing the membrane shape according to sound input. This prototype was produced by the authors in April 2007

4.1. Design Description

"Nausea Transformer": is a reconfigurable acoustic and visual system that records the environmental sound feeds in cycles of a certain time (i.e. 10 seconds), then filters that sound and delivers it to the audience with a physical response (Figure 3). The dynamics of the system, materialized as a responsive wall, is made of robotic levers, a latex membrane, sound sources and LED's which react in real time to change the behaviour of a membrane (Figure 3). The system, creates an evolutionary set of rules for what it considers a "perfect sound environment" and reacts accordingly with a sound source and a physically manifestation. If for example, the system receives "disturbing" levels of sound, it reacts in "resentment" with a louder cacophony feedback. Simultaneously, exhibits a physical relation creating "noisy" patterns on the surface through its actuators. If the input harmonizes with the set of rules of the moment, the output can be musical, pleasant and/or humorous. A pleasant sound (this is a subjective definition) is defined by low amplitude (not very loud) and by a small difference in frequency between to consecutive samples averaged for a number of samples. The membrane will try to find a behavior that will lower the "noise" (or sound level) made by the viewers by attracting their attention towards it. This is a similar approach to the one previously described for using a web camera as a fitness function, but in this case the lower the noise the higher the fitness.

The users interact with the result by giving it "empathy" or "repulsion" feedback and the system learns to adapt itself to the environment.

5 Future Work and Conclusions

The concepts described in this short paper result from work carried out by the authors to build working prototypes for responsive surfaces, actuated by shape memory alloys. Each actuator is controlled by a mixture of distributed, embedded, digital, and analog circuitry. Our prototypes development was both satisfying and awe-inspiring; testing upon the aesthetic possibilities and technical opportunities of our models has allowed us to conceptualize more fully functional applications. Nevertheless, much more work, formal testing and usability evaluation with a set of selected subjects, following international standards, remains to be done.

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