SURFACE CHANGE: INFORMATION, MATTER AND ENVIRONMENT

Surface Change project

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Abstract. Over the past decade, there has been an increasing interest in exploring the capacity of built spaces to respond dynamically and adapt to changes in the external and internal environments. Such explorations are technologically and socially motivated, in response to recent technological and cultural developments. Advances in embedded computation, material design, and kinetics on the technological side, and increasing concerns about sustainability, social and urban changes on the cultural side, provide a background for responsive/interactive architectural solutions that have started to emerge. This paper presents an ongoing design research project driven by an interest in adaptive systems in nature and a desire to explore the capacity of built spaces to respond dynamically. The paper underlines architecture’s inseparable link to technology and projects a vision of architecture that, through its capacity to change and adapt, becomes an integrated, responsive, adaptive and productive participant within larger ecologies.

Keywords. Responsive architecture; dynamic environments; mechatronics; kinetic material systems; embedded systems; shape memory alloy.

1. Introduction

Thanks to current technological achievements, broadening of scientific knowledge, and greater understanding of the underlying processes that govern metabolisms of natural world, we are able to see deep connections between the made and natural worlds. With such an expansive context comes an ability to effectively and productively integrate new knowledge, information, methods and techniques back into the design and production of architecture. Confluence of various technologies and their assimilation is altering the way we perform, organize
and distribute our activities and materials. We now expect more from architecture. We expect buildings not only to house and facilitate various modes of human activity but also to adapt to, behave, respond, and accommodate the flow of energy and information.

Behaviour, adaptation and responsiveness are characteristics of live organisms; architecture on the other hand is structurally, materially and functionally constructed. But the influence of the “organic paradigm” is changing attitudes towards architectural adaptation, behaviour and performance and altering the system of reference we use for design conception (Brown, 2003). Recent thinking in science is bringing down the traditional concept of nature as a closed system governed by static rules, recognizing that everything in nature operates within dynamic and open systems (Leach, 2004). This presents a potent context for rethinking the conceptual model of architecture. Recent attitudes towards materialization and material processes (Achim Menges, Neri Oxman, Rachel Armstrong), architectural assembly and its construction (Skylar Tibbits), as well as localized control of the interior environment (Michelle Addington) remind us that processes of building and consuming architecture could be seen and practiced as life sustaining metabolic processes. The ambition to view architecture as a form of artificial life is fuelled on one hand by “material shifts occurring in the domains of energy, resources, and technology” (Brownell, 2008) and on the other by grasping a deeper connection between biological and cultural systems. In a world of depleting resources these developments might hold a key for establishing a holistic relationship between made and natural worlds; these approaches that liken architecture to a living organism propose fundamentally different attitudes towards materialization, form, performance and construction of the built environment. New content for architecture is being formulated that relies on the integration of dynamics/change into architecture – dynamics that don’t address kinetic movement only but include flows of energies, material and information.

2. Change | Exchange | Flow

Thinking in terms of exchange, dynamics, energy, and flow brings forward fundamentally different attitude towards materialization, form, performance and construction of the built environment. Rayner Banham (1965) reminds us that two basic ways of controlling environment was by hiding under the tree/tent/roof (in other words, by building a shelter) or by mediating local environment by campfire. He points out that “a campfire has many unique qualities which architecture cannot hope to equal, above all, its freedom and variability.” This observation hints at an unexplored potential to re-conceptualize the environmental control. By shifting a discourse from form to system Banham locates architecture’s agility not
in its formal and structural expression but in the realm of building systems/technology (Kulper, 2012) emphasizing that architecture’s relationship to technology must intensify in order for architecture to stay relevant. He alludes to technology’s capacity to deliver a radically different way of living as well as frame future architectural discourse and experimentation. This predicates the most recent attitudes about environmental control that mediate conditions locally not globally and in relation to a body not space – relying on a material that does not need thermal mass but regulates the heat exchange within a thin zone of a few millimetres (Addington, 2008).

Similarly to Banham’s focus on building systems, Gordon Pask (1969) emphasizes architecture’s “operational” capacity (and its “intimate relationship” to cybernetics) by pointing out that “architects are first and foremost system designers”. The focus on architectural systems from the organizational and operational aspects extends Bahnam’s idea of the flow of energy to include the flow of information. Several projects/ideas that developed in the late 60’s and early 70’s such as Cedric Price’s Fun Palace, Negroponte’s Soft Architecture Machines, Eastman’s concept of “adaptive-conditional architecture” began to explore “intelligence” and programmability of architecture’s processes and spaces in order to facilitate the flow of information between spaces and users.

Current technological achievements as well as expansion of our understanding of the underlying processes in nature brought about a new generation of projects exploring deep connections between made and natural worlds. In 2003 Kas Oosterhuis and his Hyperbody research group designed and constructed the Muscle, a working prototype of a “programmable building that can reconfigure itself”. The Muscle is the first in a series of Pro-active Architecture (ProA) projects that study design of responsive buildings that exhibit real-time behaviours and adjust shape in response to changing environmental circumstances. The Muscle is a pressurized soft volume, wrapped in a mesh of tensile Festo “muscles,” which can change their own length and, thus, the overall shape of the prototype. The public connects to the prototype by sensors and quickly learns how the Muscle reacts to their actions; the Muscle, however, is programmed making the outcomes of interactions unpredictable. The ProA projects test capacity of buildings to respond in real time and explore a range of enclosures and programmatic situations. They demonstrate that responsive and kinetic architectural systems are not so technutopian and that spaces that move, transmit information, or adjust to a feedback could perhaps become a reality of our inhabitation in the future. They offer a promise of a “total” environment that could be inhabited, touched, moved into action and above all responsive. Surfaces/spaces like these could be at the same time architectural spaces and through their agility have a capacity to adjust to a productive role of harvesting or distributing energy or information.
3. Surface Change Project

Buildings that change in real time can be many things: they can change their functionality, perform several functions at the same time, change form and physical location, harvest and distribute energy. The Surface Change project is an ongoing design research project focused on the integration of information, matter and environment. The ambition is to develop technological/tectonic solutions that can provide buildings with a (biologically inspired) capacity to transform and adapt. A fully developed project will result in a system by which responsive dynamic structure/skin will be capable of altering its shape or its regions based on environmental conditions and the nature of use. At the same time the system would address questions of energy capture and energy harvesting. The goal is to develop technologies and designs capable of transforming static building components into active responsive surfaces that produce added functionalities in architectural and urban environments and enable architecture to become a productive participant within larger ecologies.

The ambition of this phase of the project is to explore a material system that would make movement and adaptation possible without employing mechanical components. The SKiN project (first phase of the Surface Change project), presented here, consists of small scale prototypes of an adaptive kinetic surface capable of spatial modulation and response to environmental stimuli by using shape memory alloy (SMA) as an actuator. The presented work focuses on the layering of material system and studies of its movement.

3.1. MATTER: MATERIAL SYSTEM ACTUATION AND LAYERING

Material systems in nature don’t distinguish between material and structure. In order to achieve adaptation and responsiveness they involve movement (Jeronimidis, 2004). This movement is both local and global resulting in a complex pattern produced by accumulation of the local movement effects. Furthermore, material systems in nature don’t distinguish between structural and functional material instead, variation of material properties determines and fosters certain behaviours that result in change of form, shape or location. Information travels through integrated material layers and functional needs inform material and structural distribution. The SKiN project was inspired by these characteristics of material systems in nature. We were interested in producing and understanding the “mechanism” of surface movements that would capitalize on local movements to generate a global pattern. At the same time we wanted to relate these patterns of movement to structural and functional properties of the surface. Experimenting with flows of movement, energy and information was intended to bring us closer to a material system that would reveal qualities of “freedom and variability” possessed by natural material systems, and enable us to harvest the power of phenomena in a more effective way.
We began the movement studies by focusing on actuation of the surface and designing a soft network with movable joints. This soft kinetic network (SKiN) consisted of “V” shaped memory alloy joints embedded in the silicon tubing. The network joints were “programmed” to open and close and by doing so to generate movement of the entire network. This experiment examined SMA wire joint capacity to act as a point source of actuation of the surface. To better understand the gradient of movement the grid was restricted by anchoring joint points to a flat surface in a variety of configurations. Depending on the configuration, the behaviour ranged from expanding grid cells to vertical movements of the grid’s regions. The vertical movement was surprisingly agile and pronounced. It reached its maximum when end points of the grid were anchored (Figure 1). These studies suggested potential structural capacity of the surface with pattern of anchoring directly related to the three dimensional spatial delineation.

The second experiment examined SMA wire capacity to act as a linear source of actuation. Instead of “V” joints we used ‘long’ (45cm) lengths of SMA wire (baked into large amplitude (15cm) waves) treaded through the silicone tubing grid. While technically challenging, this new method of using the wire enabled easier control and more dramatic movement results. The silicone tubing grid was then integrated into a silicone surface in order to create a dynamic material system. The fusion of the grid and silicone cells created a structural yet flexible surface that achieved a certain level of material equilibrium: the SMA wire pulled the surface into a particular shape while silicone layer contained in the cells of the grid pulled the material system back to its original shape. In this experiment the accumulation of the local movements resulted in a complex global movement where each shift of a cell depended on the movement of adjacent cells or regions. To better understand and analyze the deformations we filmed the motion and used motion tracking to map the movements (Figure 2).

Both, point and linear actuation provide a good strategy to capitalize on aggregation of local movements to produce global dynamic surface effect. Point
Actuation facilitated greater variety of movement. Within this system continually reversed joints could produce twisting movement. Linear actuation produced more dramatic movement and reduced the number of connections between the electrical wire and the SMA. Combination of these two strategies could lay out number of patterns that produce dynamic surface choreographies. Tying these choreographies to functional requirements would produce surfaces or spaces with movements tightly related to their use.

In the course of these experiments we became interested in the material variability of the surface. The variability in the material system would enable different behaviour within surface regions such as variation in the speed and degree of movement and variation in surface transparency. These experiments in material variability resulted in our current preoccupation with making pillows that would hold heat storage material and facilitate heat transfer through the surface. We are currently working on this aspect of the project (Figure 3).

The pillows have a two-fold role: to store and transmit the heat, and to participate in the movement/deformation of the surface by changing the volume of the diagrid cell. This builds upon Banham emphasizes on “freedom and variability” of a campfire. But instead of a localized heat source specific to its placement within the space the proposed pillows would work as a distributed system that can be activated locally and only where needed. Viewed in this context of flow and exchange a “campfire” can become an intelligent surface capable to instil the “freedom and variability” into architectural form/space/surface by overlapping the phenomena and flow with materiality of architectural environment. This approach would offer an opportunity to suspend a challenge of finding a non-permeable and clearly defined boundary between inside and outside in exchange for a surface that
fosters constant flow of information, matter and energy and through its own dynamics delineates and forms agile spaces.

The broader goal of the project is to design elements, structure, surface and performance of the kinetic material system as integrated layers that make up a “tissue” capable of accommodating movement related to human occupation, energy harvesting and different external/environmental influences, where two way relationships exists not only with users but with the environment as well.

3.2. INFORMATION, MATTER AND ENVIRONMENT

Our goal to design an integrated, “tissue” like material system that has a two way relationship with users and the environment required integration of sensory input and other kinds of external and internal data. We used Arduino microcontroller platform to explore these possibilities. Arduino was used to control the application of power to the SMA string as well as to incorporate sensory input and other external information. Firefly plug-in bridged the gap between Grasshopper and Arduino and was used among other things to integrate local historical weather data as an input that would allow for our surface to respond to dynamic patterns. Movement of the surface became an abstract representation of changes in temperature. The prototype was also equipped with photo sensors that would react to the change in light level. These sensors were only a place holder for a more sophisticated setup that would include temperature and humidity sensors capable of collecting a real time weather data and influencing the movement of the surface in real time.

Bringing in historical weather data enabled us to actuate our system by bringing in external information in order to explore the connection between spatial...
modulation and environmental input. We achieved our goal of implementing dynamic data patterns and yielding dynamic geometric responses.

Tying the patterns of movement produced by environmental input with functional requirements of spaces would enable surfaces or spaces to adapt and respond to external environmental conditions as well as to functional requirements of use (Figure 4).

Next iteration of this exploration will address direct relationship between the environmental input and specific spatial configuration. In other words, the particular input should be able to produce specific formation of the surface that is related to the functional requirements.

4. Conclusion

In summary, the proposed surface is organized around the network of embedded “muscle” wires that change shape under electric current. The network of wires provides for a range of motions and facilitates surface transformations through soft and muscle-like movement. The material system developed around the wire network is variable and changes its thickness, stiffness, or permeability within its continuous composite structure. The variability in the material system enables it to (a) behave differently within surface regions; (b) vary the speed and degree of movement; (c) vary surface transparency; and (d) provide other levels of performance such as capture of heat produced by the muscle wire and distribution of
heat within the surface regions. The main idea is that variability of the material system and its capacity to adapt can bring us closer to the seamless material integration and greater environmental responsiveness found in biological organisms.

In the next phase of the project the focus will be placed on scaling up of the material system, further pursuit of seamless integration of the SMA (and other smart materials) into a tectonic material system and development of a more robust micro-controlling and sensing system.

Working with smart materials presents a significant challenge especially on the scale of an architectural element or surface. Traditionally architectural components are assembled using several different material layers and every one of them has its specific role and material properties. Smart materials, on the other hand, are not artifacts; they are technologies of motion, energy, and exchange. Their integration in architecture offers an opportunity to re-calibrate materialization of architectural components and surfaces. The challenge is to build architectural assemblies that integrate and fully utilize the capacities and properties of smart materials. The functional qualities of smart materials/technologies that transfer energy and/or information would have to achieve a full overlap and integration with structural/tectonic functions of a material system necessary for architectural applications. In this way the change of scale, currently one of the greatest challenges in the projects of this kind, would be more effectively addressed. Experimenting with fuller integration of SMA was one of the aims of our project. The next phase of the project will take this further by changing the scale of the system and attempting to capitalize on discrete and local movements to produce larger global effect on the surface.

This project is situated between several disciplinary territories. By exploring theories, techniques and tools of architecture, engineering, material science and cybernetics the goal is to develop technologies and designs that are capable of transforming static building components into active responsive surfaces that produce added functionalities in architectural and urban environments.

If we were to accept change as a fundamental contextual condition, architecture could then begin to truly mediate between the built environment, the people who occupy it and the larger context. As Ed van Hinte et al. (2003) note, “instead of being merely the producer of a unique three-dimensional product, architects should see themselves as programmers of a process of spatial change.” The principal task for architects is to create “a field of change and modification” that would generate possibilities instead of fixed conditions.

Acknowledgements

Special thanks to Richard Cotter and Adam Onulov, students of architecture in the Faculty of Environmental Design, and Todd Freeborn, PhD candidate in electrical engineering at the Schulich
School of Engineering, for pursuing this project with enthusiasm and dedication. The project was made possible by the University of Calgary seed grant.

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