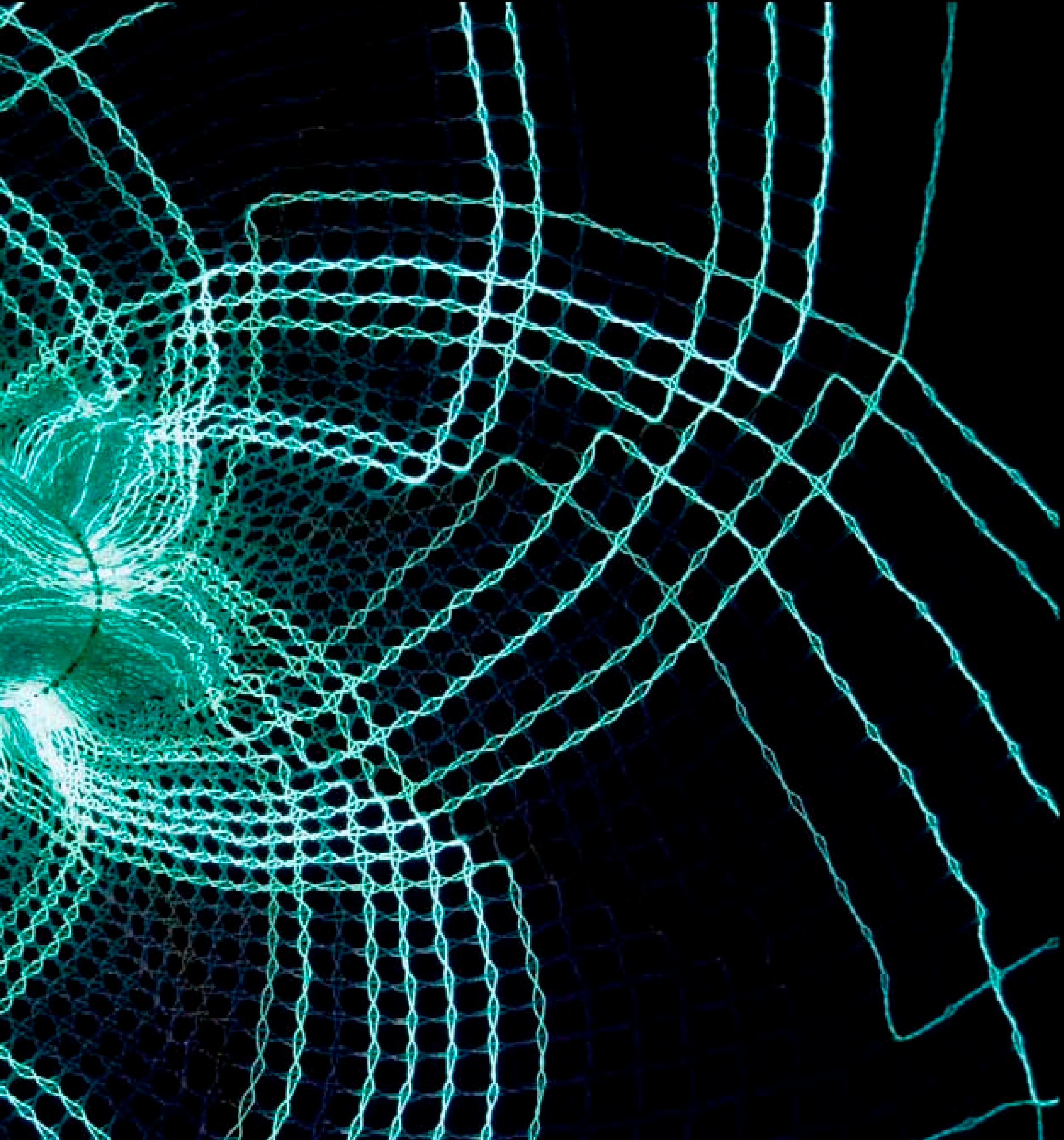
Responsive Textile Environments

Edited by Sarah Bonnemaison and Christine Macy



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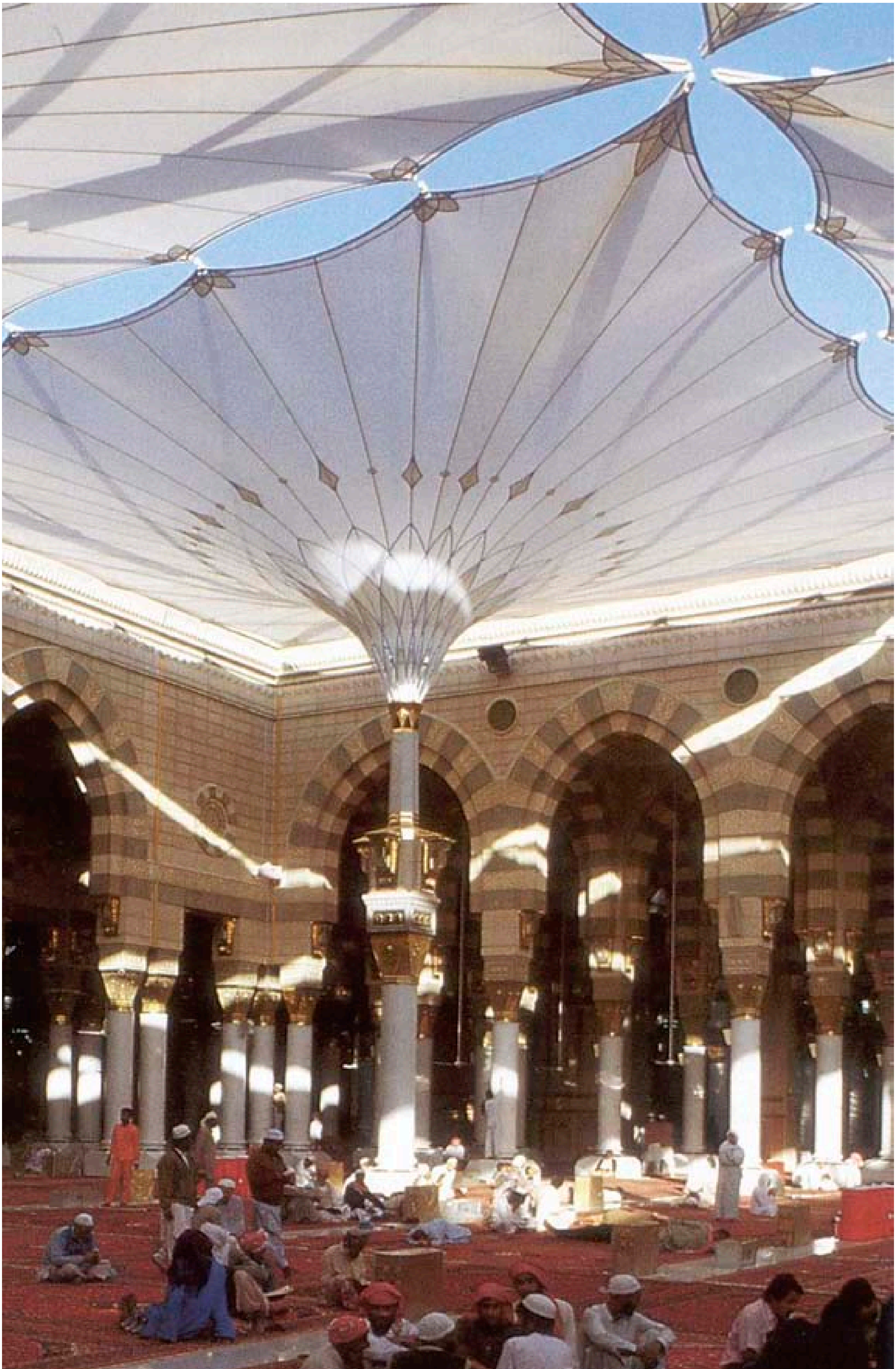


Responsive textile environments

Sarah Bonnemaison and Christine Macy
Dalhousie University

1 Convertible Umbrellas for the Courts of the Prophet's Holy Mosque, Mahdina, Saudi Arabia, 1992, Bodo Rasch
Six 17m x 18m convertible umbrellas provide shade in each of the two courtyards of the mosque.

The world of textiles is the fastest growing field in architecture and design today. As Matilda McQuaid says in her catalogue essay for the *Extreme Textiles* exhibition, "What can be stronger than steel, faster than a world's record, lighter than air, safer than chain mail, and smarter than a doctor? Hint: it is in every part of our physical environment – lying under roadbeds, reinforcing concrete columns, or implanted into humans."[1] Textiles, of course is the answer to her riddle, especially technical, high-performance textiles.

Many designers, artists and architects are creating objects and environments that combine these new textiles with software, robotics and sensors. Whether their focus is clothing or immersive environments, their aim is to make textiles that interact with their users not only in visual or tactile terms, or even by being mobile, but which use digital interfaces to respond in all of these ways. According to Lucy Bullivant, the impact of these textiles "is phenomenological, meaning that the body is able to directly experience its environment in a very direct and personal way".[2] As a result, we are seeing a whole new area of avant-garde design — from clothing to large tensile structures that incorporate the event into the artifact — an approach that is valued by museums striving to engage their publics in ever-more interactive attractions and by manufacturers seeking new markets.

From the wearable interactive textile to architectural-scale tensile structures, new textiles are fundamentally changing the way we think about and relate to our environment. Textile-based buildings "range from flexible skeletons and meshworks skins to structures that move and respond to their occupants," says architect Philip Beesley.[3]

2 *Vilkas* Dress
Joey Berzowska, Hanna Soder, Marcelo Coelho

Vilkas's kinetic hemline rises over a 30 second interval to reveal the knee and thigh. The wearer can wait for the hemline to fall, which can take several minutes, or actively pull it back down.

These new designs are the products of interdisciplinary collaborations. Clearly, a reactive or interactive garment or environment requires not just software specialists, designers of robotics, and electrical engineers, but often also materials scientists, chemists, specialists in nanotechnology and biomedical engineering. The *Am-I-Able* network for mobile and responsive environments is the result of one such interdisciplinary collaboration, with principal researchers from the Extra Soft Labs (XS Labs) at Concordia University (Joey Berzowska), the Banff New Media Institute (Sara Diamond), and the School of Interactive Arts and Technology at Simon Fraser University (Ron Wakkary). It explores the creative use of interactive technologies in the environment, through creating and adapting clothing, furniture, and the built environment to become communication devices that facilitate personal expression as well as multi-point communication between individuals and groups.[4]

A number of fiber artists are designing clothes that interact with their wearers. At the XS Labs, Berzowska and her research team have used interactive technology to create versatile electronic textiles that are animated, change their shape, augment the body's physical characteristics, and store memory.[5] Examples include the *Kukkia* dress, with its flowers that slowly open and close on their own, and the *Vilkas* dress, with a hemline that rises above the knee when electrically stimulated[6] (Fig. 2); and *Memory Rich Clothing* — a series of reactive body-worn artifacts that display their history of use, effectively communicating embodied memory.[7] The goal for these electronically enhanced garments is to promote touch, physical proximity, and interaction in social networks as well as intimate settings. Other artists are exploring the performative aspects of interactive technology with the environment, such as Thecla Schiphorst and Susan Kozel's *whisper* — a networked environment of input and output devices located in the clothing of participants and in the installation space. Devices "whisper" to, or "hear" the whispers of other devices in proximity.[8] Bullivant explains,

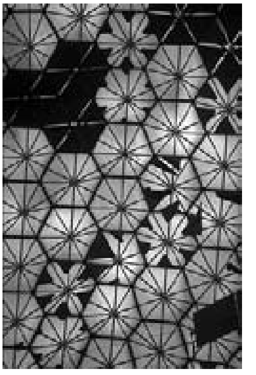
> The very nature of responsive environments, involving functioning through interfaces that facilitate interaction, is a form of mediation between inner world self and the outside world, and it presupposes some kind of event that is not wholly pre-programmed. Input from the real world received via sensors is essential, as are output devices in the form of actuators (mechanisms that transform an electrical input signal into motion), displays and other sensory phenomena to engage with users.[9]

The key point here is that the interaction is not pre-programmed but evolves according to the actions and responses of the people involved as well as input from the natural environment, such as sun, wind and changes in temperature. This kind of research continues designers long-standing value for the qualitative aspects of identity, memory, sociality, and quality of life that are central to human well-being. By considering environments and architectures as well as personal technologies, this incorporation of electronics into design emphasizes the link between individual wellness and social well-being — focusing on lifestyle and relationships, instead of focusing on biometric sensors with a quantitative approach to wellness, not to mention the issues of invasion of privacy and surveillance.

Architects have always collaborated with specialists. The creation of responsive textile environments furthers this type of research in the same spirit.

An early example of "responsive" a architectural environment was developed by the visionary thinker R. Buckminster Fuller in his *Garden of Eden* geodesic dome of 1955, which used two revolving geodesics inside each other, that opened to the outside. Fuller developed this idea further in his United States Pavilion at the Montreal Expo in 1967, designing automated retractable screens within the cellular framework of the geodesic that — triggered by a light sensor — selectively opened and closed as the sun moved across the sky (Fig. 3). Fuller used the analogy of a "breathing skin" ,

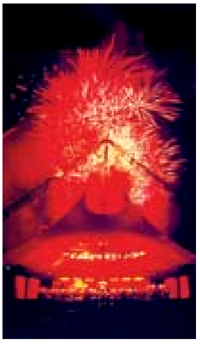
> anyone looking at the geodesic dome in Montreal saw a very beautiful piece of mechanics. It did all kinds of things to your intuition. You saw there were curtains that could articulate by photosynthesis [light sensors] and so forth, could let light in and out. It is possible, as in our own human skin [that] all of the cells organize, so that some are photo-sensitive and some are sound-sensitive, and they're heat-sensitive, and it would be perfectly possible to create a geodesic of a very high frequency where each of these pores could be circular tangencies, of the same size. One could be a screen, other breathing air, others letting light in, and the whole thing could articulate just as sensitively as a human being's skin.[10]



3 US Pavilion for Expo 67, Montreal, R. Buckminster Fuller and Shoji Sadao

Traditionally, tensile architecture has involved shelters built with posts and stretched fabric, from the age-old hand-woven woolen tents of desert nomads to modern PVC-coated membrane roofs for stadiums and inflated structures. Modern tensile architecture aims to clearly separate the elements working in compression (posts and columns) and those working solely in tension (membrane and cables).[11] One of the more recent development in this field is a possibility that the textile membrane might change over time, either through movement or in its properties.

The earliest example of a transforming high-tech tensile structure was a convertible roof designed by Frei Otto, the pioneer of lightweight structures, for an outdoor performing space in the courtyard of an abbey at Bad Herzfeld, Germany. A more recent example is a project by FTL Design Engineering for a transportable music pavilion used by the New York Philharmonic and Metropolitan Opera to bring concerts and operas to all parts of the city. This



4-5 Carlos Moseley Music Pavilion, New York City FTL Design and Engineering structure is deployed by what we could call large mechanical "actuators", in the form of extendable cranes on trucks that hold the membrane of the tent in place (Figs. 4-5).[12] With the advent of computer-controlled pneumatic and mechanical operators, solar cells, and an ever-increasing miniaturization of computerized control systems, the control and operation systems for tensile structures have become increasingly sophisticated. An outstanding example is Bodo Rasch's project for 300 umbrellas on the roof of the Great Mosque in Mecca, solar powered and free of cables (an essential feature because of their historically-sensitive location) due to a battery incorporated in the base of each. A smaller version of the project was realized in 1992 in two courtyards of the Prophet's Holy Mosque in Medina (Fig. 1).[13] In these projects, a computer chip triggers the umbrella to close under high winds, so that the delicate structures are not damaged. This is an example of tensile architecture in motion, exploring basic responsive capabilities to address environmental conditions (solar exposure, wind load).

The essays that follow present the work of a number of artists, designers and architects working with responsive textile environments, at multiple scales ranging from the most intimate scale of body and clothing to the most extended scale of a dispersed animated "architecture" that floats on the air over a large crowd of viewers. These essays present a radical addition to the traditional sense of textile design by incorporating communication devices such as mobile telephones, software programs, sensors and actuators in order to create a relationship between the physical, spatial and digital realms.

At the scale of the body and of personal space, Carole Collet's essay in this volume surveys a range of projects created by her students in the Textile Futures Course at Central Saint Martins College of Art and Design in London. These projects employ a wide range of technologies, some older (thermochromic inks, electroluminescent wire, photovoltaic cells) some more recently developed (shape-memory alloys). Responding to changes in temperature, wallpapers change their appearance when warmed by solar radiation, and wearable textiles when brought into contact with body heat. Miniaturization of mechanical actuators allows for small adjustments to shape and introduces motion at an intimate scale, as we see with one student's pillow that waves its tassels when stroked. Contemporary concerns with sustainability and ecology enter into this work as well, as students explore the intersection between cutting-edge technologies and recycling, and the marriage between organic textiles and synthetics.

6 Textile Futures students
Central Saint Martins College of Art and Design, London

7 Rachel Wingfield
working on the *BioWall*

8 Silk-steel textile blend
in installation by Mette Ramsgard Thomsen

A graduate of the Textile Futures course, Rachel Wingfield, has set up a design-research firm of her own in collaboration with her partner Mathias Gmachl. Their firm, Loop.pH has developed a number of notable installations that employ sensors to create animated surfaces and textiles. Employing both flat print-based techniques and more three dimensional technologies such as knitting, crocheting, and basket-like systems, their projects register input from human movement, weather conditions, and sunlight to "close the loop" between person, artifact and the larger — even global — environment. Wingfield and Gmachl's interest in pattern derives not only from the world of printed textiles, but from the insights of D'Arcy Wentworth Thompson and later Buckminster Fuller, who saw the perfection of natural forms, both organic and inorganic, as revealing essential truths about the physical world. In this sense, they are continuing a long history of designers working with geodesic, self-stable, and spiral geometries to express organic unity or (to use a contemporary term) sustainability.

In her work, the architect Mette Ramsgard Thomsen views "form" as a verb and morphogenesis as the process of biological systems organizing themselves in and in relation to their environment. She situates the "user" of the built environment in the midst of this process, developing their sense of self in the world through movement and interaction. Her *Strange Metabolisms* installation is a miniature world of scale models that she invests with metabolic qualities of movement by using film and video animation; while her other projects invite viewers to enter into the spaces enclosed by the textiles to manipulate and transform them. The inflated air sacs in her *Vivisection* piece recall the gently undulating fabric wave of Annette Messager's *Casino* that flowed silently from a portal in its installation at the Venice Biennale of 2005 to reveal a submerged world of animated creatures below. By working with a conductive silk and steel blend in her larger installations, Thomsen allows the architectural textile surface to power an interconnected matrix of sensors and actuators deployed in these projects.

Similarly, the architect Philip Beesley treats the textile matrix as a body for the dispersion of sensing and motor devices. Deriving his initial inspiration from geotextiles, Beesley has developed an evocative body of work that expands these fabrics literally and metaphorically to encompass earth and space. They also envelop their viewers in a gradual process of incorporation (although he prefers the term "digestion") so that one is never apart from, but

9 Digitally manufactured ‘breathing pore’ in textile installation, Philip Beesley

always in relation to the work. Like all the designers whose work is presented here, Beesley is interested in the interrelationship between person, textile and environment. He sees textiles as mediating — borrowing a phrase from the psychologist Donald Winnicott, he calls them “transitional objects” — between a personal sense of self and the larger environment. By incorporating sensors and actuators into his sculptural-scale textile pieces, he lends them an uncanny quality of being alive as they interact with their viewers. His collaborator Robert Gorbet has developed the networking systems that bring new complexity and subtlety to Beesley’s vision.

Lastly, Usman Haque’s work combines the personal technology of the mobile telephone with the most extended spatiality of the projects collected here, in his *Burbles* — aggregations of air-filled balloons that are lit and controlled by crowds far beneath them, who call in on their mobile phones to affect the sculpture. In all of his projects, Haque is fascinated by the unseen — from electromagnetic fields and invisible radiation on the spectrum, to scents and sounds. His projects draw out the visual potentials of these fields, making us more aware of our embeddedness in them. An as interaction designer, Haque is overt about his ethical perspective that people should have a constructive role in developing the shape and function of interactive systems, much in the same inclusionary vein that “participatory” architects such as Lucien Kroll developed in phsyical terms. In Haque’s words, people are then “more engaged with, and ultimately responsible for, the spaces that they inhabit.” This is surely a significant goal for responsive environments.

10 ‘Talking’ to the air-borne *Burble* with a mobile phone Usman Haque installation

Notes

1 Matilda McQuaid, *Extreme Textiles: Designing for High Performance*, New York: Princeton Architectural Press, 2005, p. 11.

2 Lucy Bullivant, “Introduction”, *Responsive Environments: Architecture, Art And Design*, London: V&A Publications, 2006, p. 7.

3 See Philip Beesley, Sachiko Hirosue, Jim Ruxton, Marion Tränkle and Camille Turner (eds.), *Responsive Architectures, Subtle Technologies*, Cambridge, ON: Riverside Architectural Press, 2004.

4 http://www.amiable.siat.sfu.ca/index.html

5 http://www.xslabs.net/intro.html

6 http://www.concordia.ca/clusters/textiles/ See also Joanna Berzowska and Marcelo Coelho, “Kukkia and Vilkas: kinetic electronic garments”, *Proceedings, Ninth IEEE International Symposium on Wearable Computers*, 18-21 (October) 2005, pp. 82-85.

7 Joanna Berzowska and Marcelo Coelho, “Memory Rich Clothing,” *Extended Abstracts, Conference on Human Factors in Computing Systems* 2006, ACM, Montreal, Canada; and Joanna Berzowska, “Memory Rich Clothing: Second Skins that Communicate Physical Memory,” *Proceedings of the 5th conference on Creativity and Cognition*, ACM Press, 2005, pp. 32-40.

8 http://www.fondation-langlois.org/html/e/page.php?NumPage=46

9 Bullivant, “Introduction”, p. 9.

10 Fuller quoted in Joachim Krausse and Claude Lichtenstein (eds.) *Your Private Sky: R. Buckminster Fuller, The Art of Design Science*, Baden: Lars Müller Publishers, 1999, p. 428.

11 See for example, Klaus-Michael Koch with Karl J. Habermann, *Membrane Structures: Innovative Building with Film and Fabric*, New York: Prestel, 2004; and Conrad Roland, *Frei Otto: Tension Structures*, New York: Praeger Publishers, 1970.

12 http://www.ftlstudio.com/ See also Robert Kronenburg, *FTL: Todd Dalland Nicholas Goldsmith, Softness Movement and Light*, Great Britain: Academy Editions, 1997. For other mobile and demountable tensile projects, see Oliver Herwig, *Featherweights: Light Mobile and Floating Architecture*, New York: Prestel. 2003; Robert Kronenburg, *Portable Architecture*. Oxford: Elsevier/ Architectural Press, 2003; and Robert Kronenburg (ed.), *Transportable Environments: Theory, Context, Design and Technology*, London: E & FN Spon, 1998.

13 http://www.sl-rasch.de/ See also Frei Otto and Bodo Rasch, *Finding Form: Towards an Architecture of the Minimal*, Stuttgart: Edition Axel Menges, 1995.

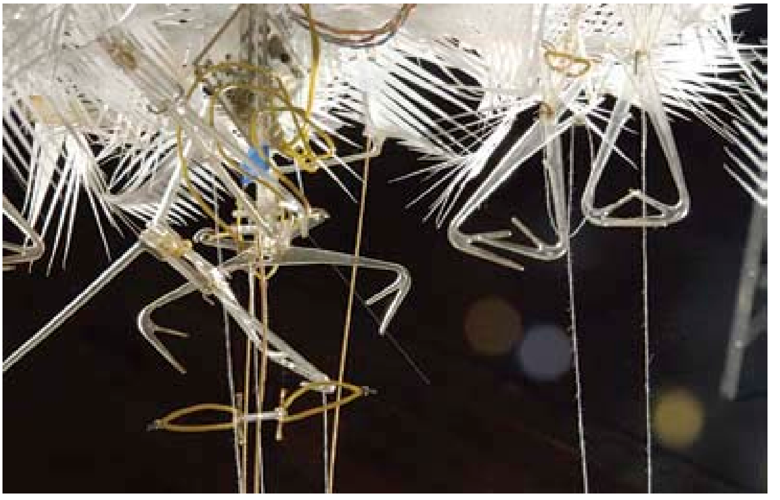
Hylozoic Soil Control System

Robert Gorbet and Philip Beesley
University of Waterloo

1 Hylozoic Soil, 2007

Hylozoic Soil is one of a series of large-scale textile installations that pursue reflexive, kinetic architectural environments. Recent generations of this work have employed sensing and actuator mechanisms, and this essay focuses on the control system developed for these actions. The microprocessor-controlled system includes open-source 'Arduino' hardware extended by new control boards, shape-memory alloy actuators and space sensors arranged in a distributed interactive system.

The textiles in these installations feature collective patterns of movement by mechanical components that respond to viewers' movements in the exhibition gallery or space. The structural matrix which supports these components — and gives shape to the textile — is formed out of lightweight lattice scaffoldings that are digitally fabricated to precise tolerances and assembled in 'geodesic' organizations. This matrix also houses distributed networks of sensors and actuators. The structures are designed at multiple scales, from the very fine and intricate moving components, to the intermediate tessellations (tilings) of component arrays and, at the largest scale, the general structural systems. The most recent projects in this series of installations focus on integrating control systems with decentralized responsive intelligence. The work is based on a program of gradual development moving from individual figures composed of complex hybrid organisms toward immersive architectural environments that include lightweight interior-linings and durable exterior shading and filtering assemblies.

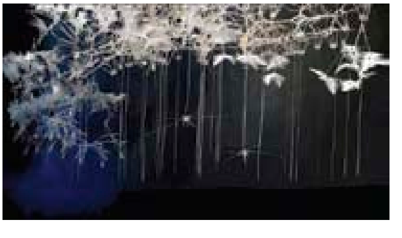


2 Implant Matrix, 2006

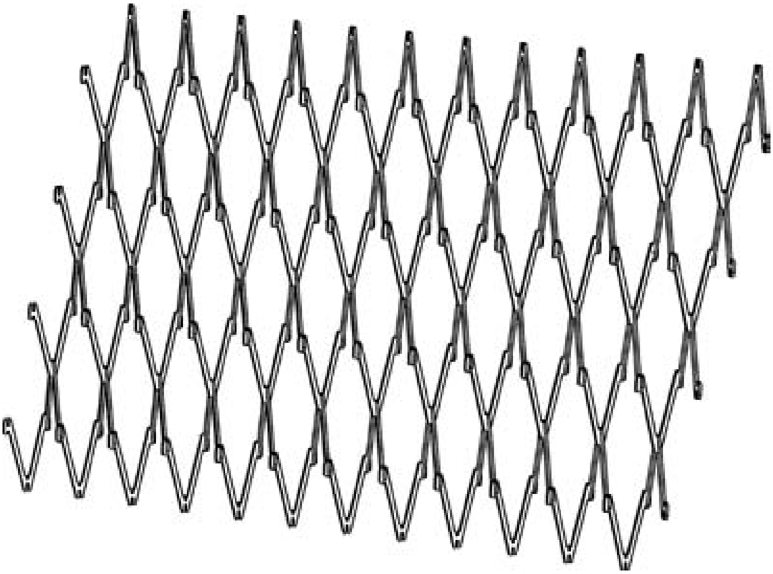
Preceding the latest work, a temporary gallery installation erected this past year in Toronto titled *Implant Matrix* was an experimental building skin equipped with layers of miniature valves and clamping mechanisms that might convert surrounding material into a living wall. By accreting and digesting surrounding matter, the matrix was designed to accumulate a new kind of living turf. The work used simple interactive systems controlled by distributed Peripheral Interface Controller (PIC) microprocessors. These systems supported a primitive intelligence that animated the structure, pursuing a kind of mechanical empathy in which the components reacted to human occupants as prey. The elements were structured using an aperiodic tessellation of rhombic cells with slender acrylic armatures that flexed perforated sheets of Mylar. Capacitance 'whisker' sensors, shape-memory alloy (SMA) muscle-wire actuators and toothed Mylar filtering valves were included within its lightweight polymer skeleton. The Implant Matrix installation included distributed sensing and actuation while retaining centralized power, intelligence, and communications.

Hylozoic Soil is a generation that builds upon work done within Implant Matrix, developing a decentralized structure where much of the system is distributed and extensible, based on localized intelligence. Occupants move within the Hylozoic Soil structure as they would through a dense thicket within a forest. Microprocessor-controlled sensors embedded within the environment signal the presence of occupants, and motion ripples through the system in response, pulling trickles of air through the mesh and drawing stray organic matter through arrays of filters.

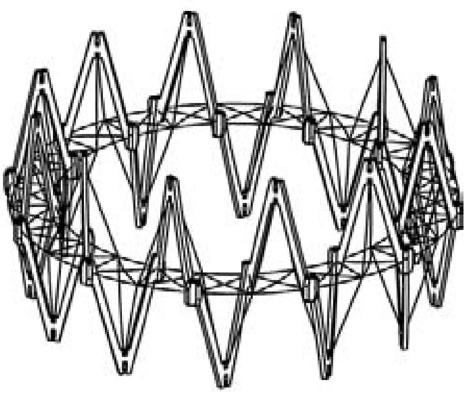
3 Hungry Soil, 2000



4 Reflexive Membrane, 2004



5 Meshwork field



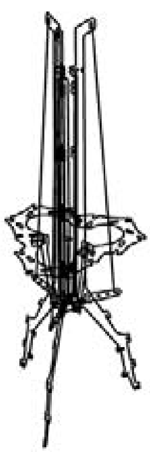
6 Meshwork 'column'

The structural core of Hylozoic Soil is a flexible meshwork assembled from small acrylic chevron-shaped tiles that clip together in tetrahedral forms. These units are arrayed into a resilient, self-bracing diagonally organized space-truss. Curving and expanding this truss work creates a flexible grid-shell topology. Columnar elements extend out from this membrane, reaching upward and downward to create tapering suspension and mounting points. Fitted into this flexible structure are hundreds of small mechanisms that function in ways akin to pores and hair follicles within the skin of an organism.

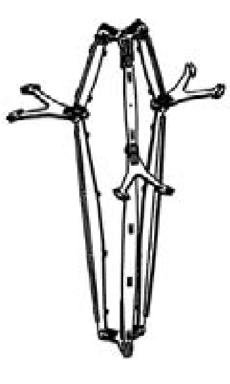
'Breathing' pores are composed of thin sheets shaped into outward-branching serrated membranes, each containing flexible acrylic tongue stiffeners fitted with monofilament tendons. The tendons pull along the surface of each tongue, producing upward curling motions that sweep through the surrounding air. 'Kissing' pores are a cousin of this mechanism. These use a similar mechanics fitted with a fleshy latex membrane and offer cupping, pulling motions. A second kind of 'swallowing' pore occurs in a triangular layout that creates a dense series of openings running throughout the meshwork. These openings contain pivoting arms in triangular arrays that push out radially against the surrounding mesh, producing expanding and contracting movements. Yellow LED lights are fitted within lower surfaces of these elements, configured to pulse in synchronization with swallowing motions. 'Whisker' wound-wire pendants are arranged in dense colonies within this environment, supported by acrylic outriggers with rotating bearings. Tensile mounts for the whiskers encourage cascades of rippling, spinning motion that amplify swelling waves of motion within the mesh structure.

Processing for this system is based on Arduino (www.arduino.cc), an open-source platform that was designed to make tools for software-controlled interactivity accessible to non-specialists. The palm-sized Arduino microcontroller board can read sensors, make simple decisions, and control devices. The microcontroller used in the platform is an Atmel ATmega168, a tiny computer-on-a-chip that contains specialized hardware to process digital signals, read analog inputs and communicate over a serial connection, based on user-designed software that resides in its memory. The first developers- Massimo Banzi, David Cuartielles, David Mellis, and Nicholas Zambetti- ran

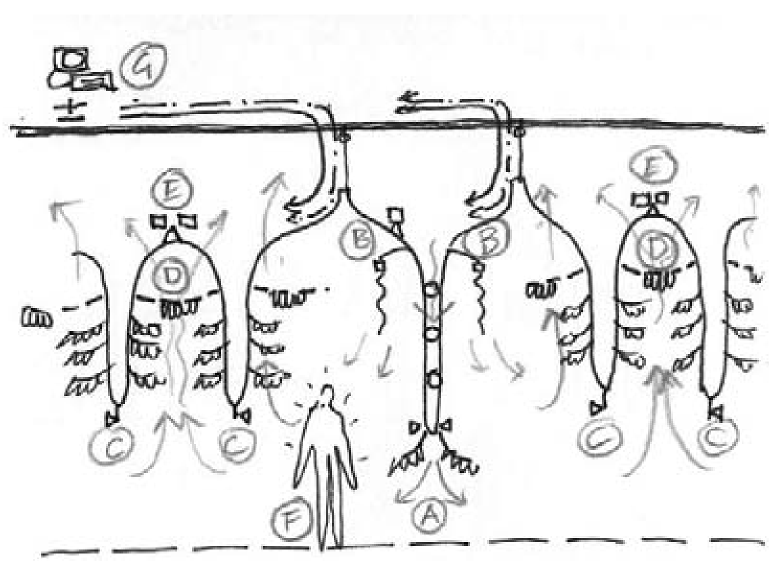
7 'Breathing' pore



8 'Kissing' pore



9 'Swallowing' pore



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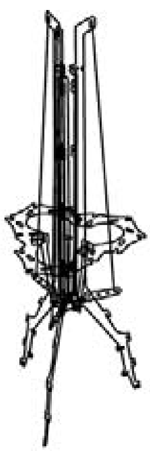

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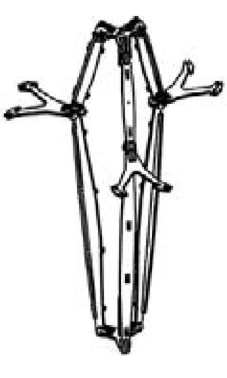

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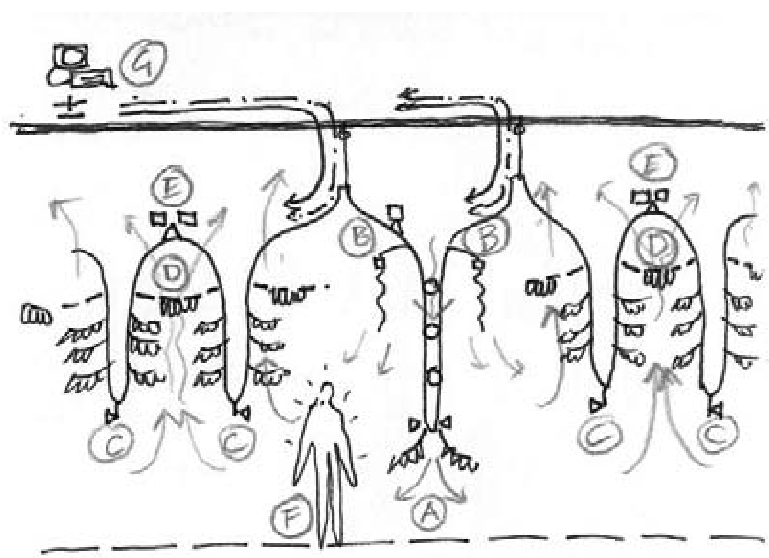
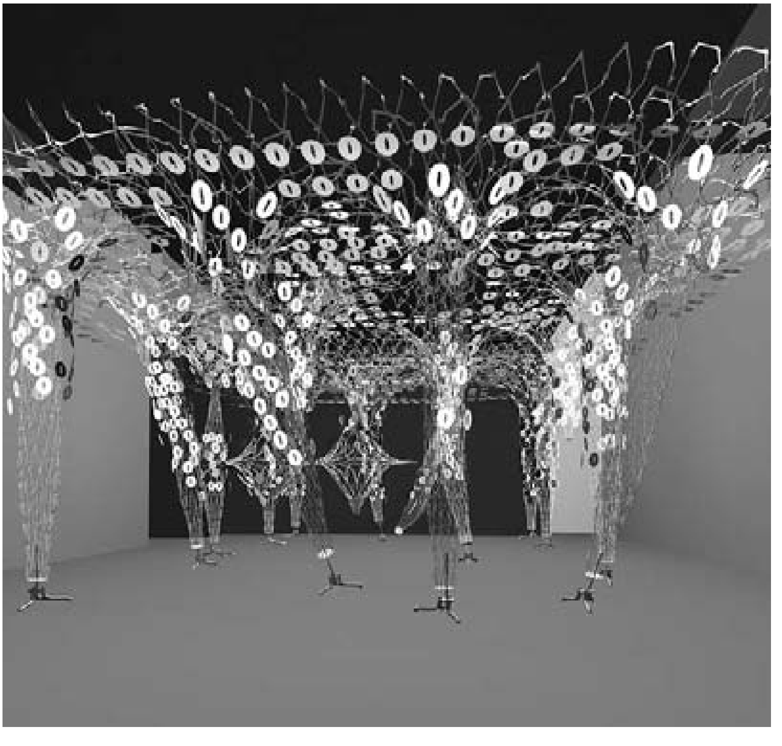
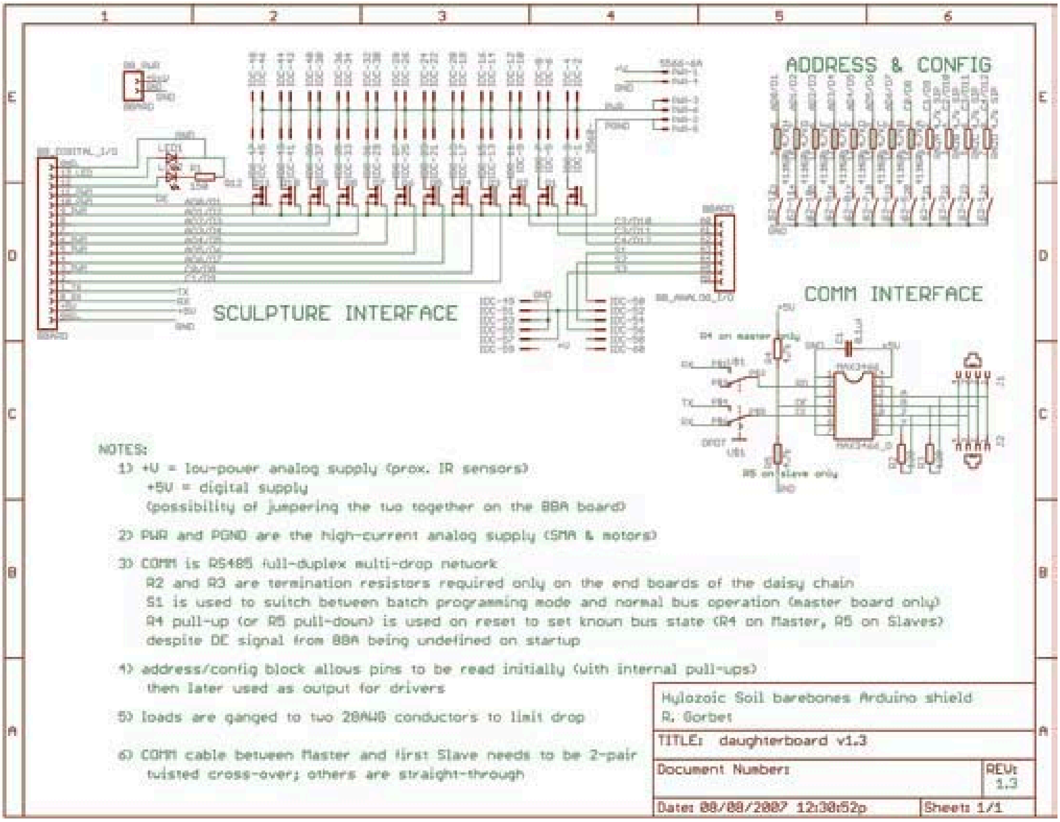


workshops that demonstrated assembly of the microprocessors and gave the board away to stimulate development. A community of developers and users now provide cooperative support, and the programming environment and documentation is written with the neophyte in mind. The version of Arduino used for Hylozoic Soil is the Bare-Bones Board, Revision C, developed by Paul Badger (www.moderndevice.com). This inexpensive implementation of the platform has a small (40mm x 60mm) footprint, and is provided fully-assembled or in kit form. It includes power regulation, timing, and external components for digital inputs and outputs that can control a range of interactive devices.

In Hylozoic Soil, each Bare-Bones Board is paired with a custom 'daughter board' to form a robust integrated unit. The daughter board provides three key additional elements to extend the function of the main board: a high-current output stage, configuration switches, and a communication interface. Twelve high-current output channels permit digital control of devices at currents of up to 1 amp per circuit at voltages up to 50 volts. Twelve switches are read by the software during initialization of the boards and can be used for functions such as configuring individual board addresses and specifying configuration data to control individual board behavior. The communication interface converts serial communication signals from the Arduino and supports distribution at high speed to a network of boards using the RS485 standard. The daughter board also provides a 60-pin ribbon cable interface for connecting actuator and sensing devices, and a two-channel power connector to distribute high currents to actuators as well as a lower current 'electronics' supply.



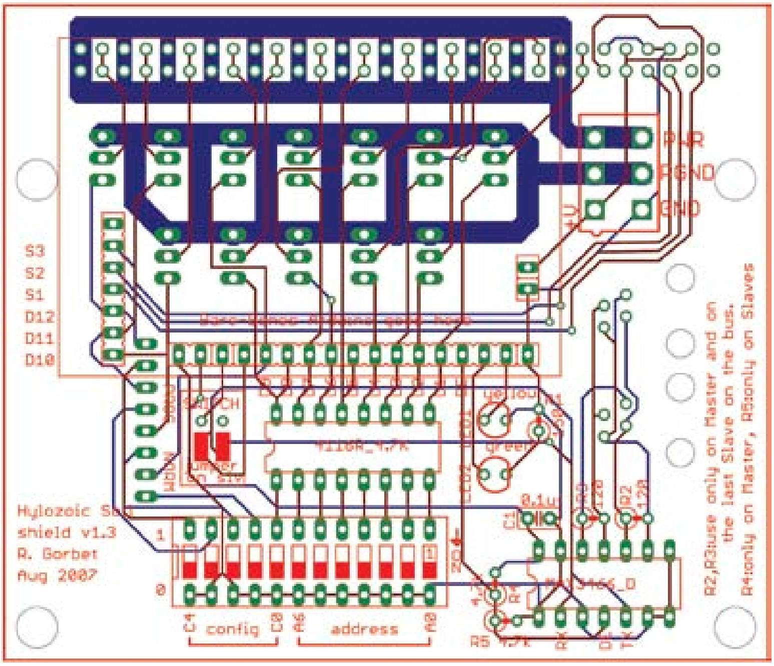
11 Hylozoic Soil, 2007



12 Hylozoic Soil, 2007

The Hylozoic Soil sculpture includes three kinds of actuator elements: 'breathing' and 'kissing' pore mechanisms actuated by shape-memory alloy 'muscle' wires, 'whisker' elements driven by small direct-current motors, and miniature LED lights. Each mechanism is designed to operate at five volts. Under software control, the output drive channels switch current from the high-current five volt supply to each of the individual actuator elements. The SMA-actuated pores are driven by ten-inch lengths of 300 micron-diameter Flexinol wire that contract when an electrical current runs through them. Mechanical leverage amplifies the 1/2" contraction that occurs in each wire and translates this into a curling motion. Whisker elements are composed of flexible wound wire strings extending from the shaft of a small three-pole motor. LED lights are combined with current-limiting resistors to form a visual actuator configured for the five volt power supply.

Each daughter board accommodates up to three analog sensors. Sharp infrared proximity sensors with varying detection ranges provide feedback that allows the sculpture to respond to occupant motion occurring near the boards. Powered by the five-volt electronics supply, the sensors emit an infrared signal and receive reflected signals from nearby objects, registering the distance of the reflecting surface and feeding that information back to an input on the Arduino board.



13 Hylozoic Soil, 2007

The Hylozoic Soil distributed system consists of 38 controller boards, all with identical hardware. Specialized functions are assigned by software setups in groups of boards, and one board assumes a supervisory role for the entire system. This 'bus controller' board manages messaging by means of a 'full-duplex, differential multi-drop' communication bus. A full-duplex implementation uses two pairs of wires: one pair for incoming information and the other for outgoing data. This allows for simultaneous communication in both directions along the bus. Each board constitutes one 'drop' of the multi-drop system. The communication system uses an RS485 communication standard protocol. In this standard, information is transferred on pairs of wires that carry differing voltages. Communication signals are detected by measuring the differential in the paired wires. This scheme, along with the use of twisted-pair cabling, makes the system less prone to noise-induced communication errors.

Individual boards all 'talk' on the bus controller's receive lines, and listen to the controller's instructions on the parallel send lines. Information is transferred from board to board via the controller. A typical message may consist of several bytes of information, and includes addressing information to route the message. The bus controller forwards messages it receives on its outgoing lines, and individual boards are programmed to ignore messages which are not for them.

This organization means that there is the potential for communication conflicts if multiple boards try to send messages simultaneously, so each board needs a way to know when it is safe to talk on the bus. In order to accomplish this without using up scarce hardware resources, Hylozoic Soil uses a 'challenge-response' model. The bus controller periodically asks each individual board if it has something to say, and the board responds. If that response needs to be retransmitted to the other boards, the controller relays it. In this way, a given board emits signals on the bus only if it has been asked to do so by the bus controller. The messaging protocol has been designed to use primarily one-byte messages, meaning that at the slowest bus speed of 9600 bits per second, the bus controller can poll the entire installation in a tenth of a second.

Several levels of behavior are programmed into the sculpture in order to encourage coordinated spatial behaviour to emerge. Software is organized into local behavior affecting isolated groups of devices, coordinated behavior between neighboring groups, and global behavior running throughout the whole system. Each board produces its own response to local sensor activity. The bus controller polls the board, and if the board's sensors have fired the board transmits sensor information to the bus controller when polled, using an 'information message'. An information message is composed of six bits containing the address of the originating board, and two bits containing sensor status information. When a board's sensors have fired, the bus controller will forward that information message on its outgoing bus. Each board listens for messages from neighbouring boards, identified by means of an address map of the devices within the installation, encoded into the software. The bus controller has information about sensor activity from all of the individual boards and is

able to control a third level of 'global' behaviour with this information. For example, if excessive activity is detected it may send out a special message to all boards to quiet down the sculpture. Similarly, it may send out a message instructing a low-level background behaviour if it detects that sensors have not fired in a while. Six bits are available for addressing, leaving substantial capacity for special messages. Messages with unassigned addresses are used for these special functions to avoid confusion with information messages originating from individual boards.

Simplicity and economy are prevailing qualities that have guided design of the system, supporting massive repetition and efficient mass-manufacturing of the assemblies. Consumption of materials is reduced to a radical minimum by employing optimized form-finding design methods. Strategies include use of efficient tensile forces and textile systems in mesh and shell forms and derivation of three-dimensional forms from thin, two-dimensional sheets of material. Space-filling tesselations and rigorously nested components derived from sheet goods contribute to this hybrid economy. Some eight cubic feet of acrylic polymer, fifty pounds of copper wire, aluminum sheet and handfuls of specialized alloys are expended, while the expanded space formed from these materials occupies some eight thousand cubic feet.

Similarly, the control system offers considerable complexity in its behaviour while avoiding large centralized computing. The distributed arrays of inexpensive miniature microprocessors achieve coherent behaviours through their distributed communication network. The intensive repetition of small information packets in the communication network and mass-manufacture of miniature physical components in the physical sculpture are similar in their approach, offering a resilient, heterogeneous whole.

Contributor biographies

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Philip Beesley maintains an experimental practice that combines architecture, sculpture and performance. His hybrid art-architecture installations have developed a distinctive body of work involving geotextile fields and interactive environments, while his built works include a series of schools, theatres and community facilities. His creative work has been recognized by the Prix de Rome for Architecture (Canada), a Governor-General's award, a number of Ontario Architects Association Awards of Excellence, and two Dora Mavor Moore Awards. In parallel with his practice, he is an Associate Professor at the University of Waterloo School of Architecture as well as the Fabrication theme leader for the Canada Design Research Network and co-director of the Waterloo Integrated Centre for Visualization, Design and Manufacturing (ICVDM), a high performance computing centre. Publications include *Fabrication: examining the digital practice of architecture* (AIA/ACADIA 2004), *Responsive Architectures: Subtle Technologies* (Riverside Toronto 2006), *Future Wood* (Riverside, 2006), *Mobile Nation* (Riverside 2007), and the forthcoming *On Growth and Form: organic architecture and beyond* (Tuns Press 2007).
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Usman Haque creates responsive environments, interactive installations, digital interface devices and mass-participation performances – encompassing the design of physical spaces and the software and systems that bring them to life. Until 2005, he was a teacher in the Interactive Architecture Workshop at the Bartlett School of Architecture in London. The recipient of numerous awards and prizes, he has been an invited researcher at the Interaction Design Institute Ivrea, Italy, and an artist-in-residence at the International Academy of Media Arts and Sciences, Japan. He is a recipient of a Wellcome Trust Sciart Award, a grant from the Daniel Langlois Foundation for Art, Science and Technology, the Swiss Creation Prize, Belluard Bollwerk International, the Japan Media Arts Festival Excellence prize and the Grand Prize Asia Digital Art Award. Haque Design + Research specialises in the design and research of interactive architecture systems. Architecture is no longer considered something static and immutable; instead it is seen as dynamic, responsive and conversant.

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Loop.pH

Rachel Wingfield and Mathias Gmachl

Loop.pH is a design and research group that aims to bridge the gap between design and the natural sciences. They specialise in the conception, construction and fabrication of environmentally responsive textiles for the built environment. It is directed by Rachel Wingfield and Mathias Gmachl. Rachel is also a Senior Lecturer with the MA Design for Textile Futures and a Research Fellow at Central Saint Martins College of Art and Design in London. Mathias is a Research Associate at the Royal College of Art in London. Loop.pH belong to an emerging generation of designers redefining conventions of how, why and with what things are made. Emphasis is placed on learning from both traditional craft based practices alongside the cutting edge of scientific and technological discovery. With a deep understanding of the complexity of ecological systems and natural cycles their approach to design and fabrication values the physical process of making as much as new and established research methodologies and theories. Rachel and Mathias are currently working on a residency at the Royal Botanical Gardens Kew and Queen Elisabeth Hospital in London. They will exhibit at the Museum of Modern Art, New York, in early 2008 and continue collaborating with Nobel Laureate John Walker on the project *Metabolic Media*.

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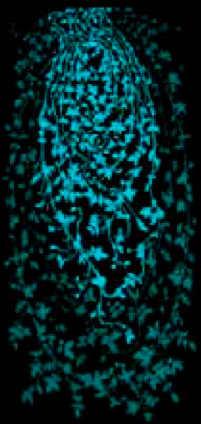

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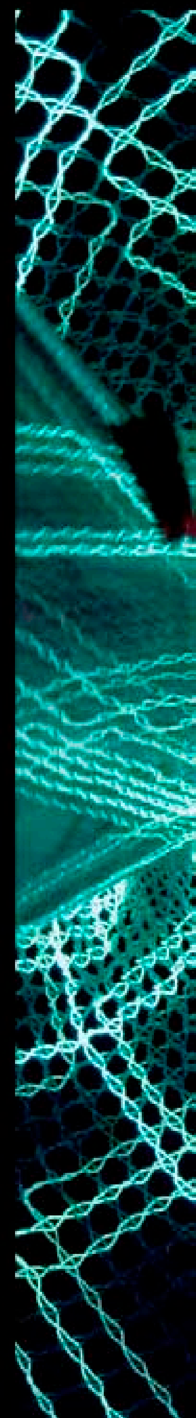

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