# Revealing the Hylozoic Ground Interaction Layer

ROB GORBET

The immersive, interactive environments of the Hylozoic series are prototypes of responsive architectural spaces that in the future will offer empathic, sympathetic environments for occupants. This chapter exposes the systems—electronics, sensors, actuators, and communications—that facilitate the Hylozoic system's interactions between environment and occupant.

One of the questions frequently asked by artists and non-artists alike is whether it is possible to make 'good' technology art. Like any artistic medium, one can find examples of varying quality, and since evaluation is often subjective, the easy answer is "yes." It can be difficult, however, to apply the traditional tests of quality—particularly recognition in gallery exhibitions and museum collections—to technology-mediated works, because rapid obsolescence and difficult documentation pathways make them expensive or impossible to maintain in exhibition environments.

facing page

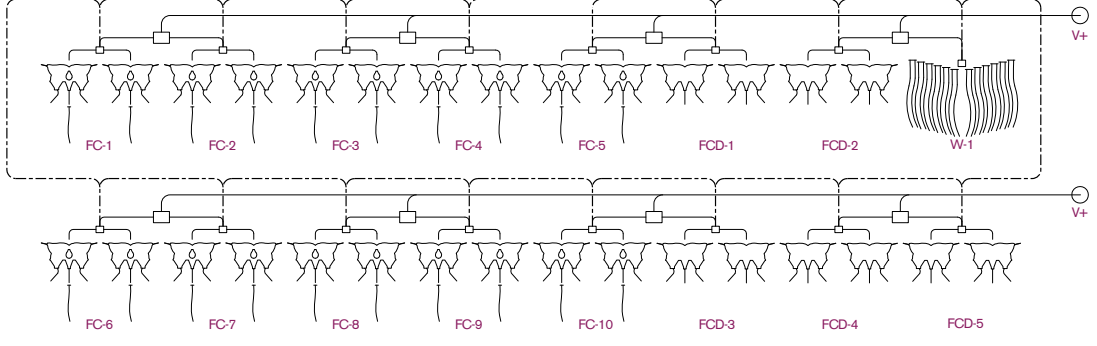1 Filter layer detail, **Hylozoic Soil: Meduse Field**, "Mois-Multi Festival," Meduse, Quebec City, 2010.
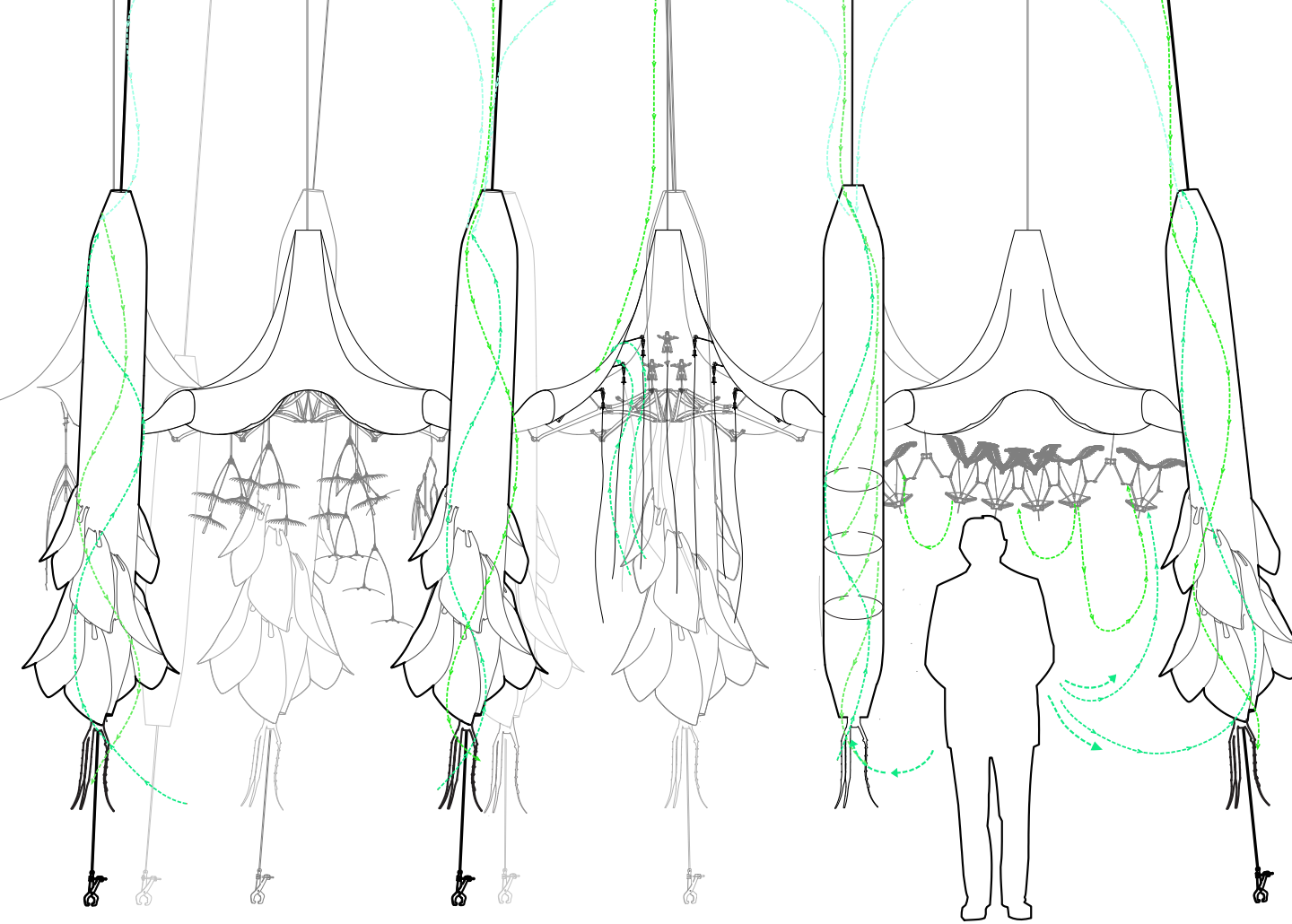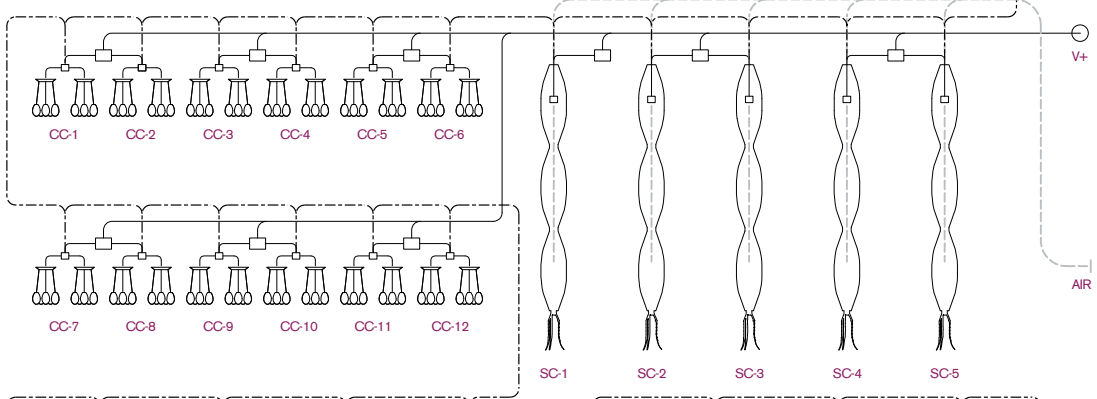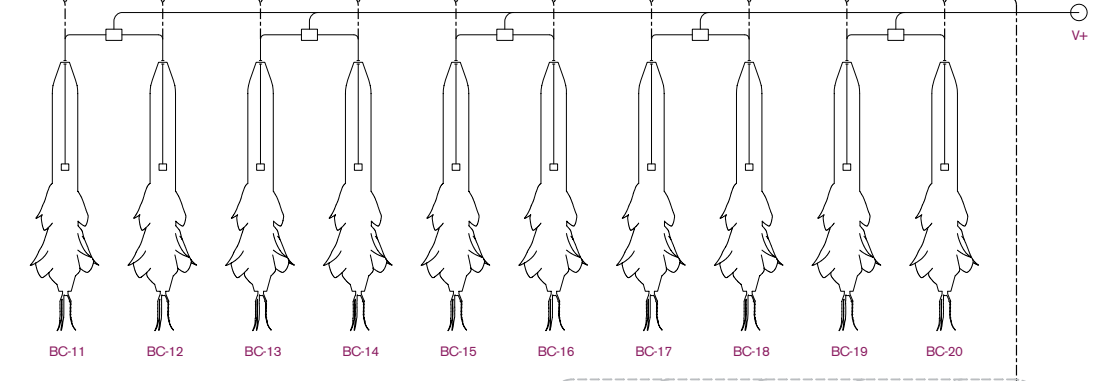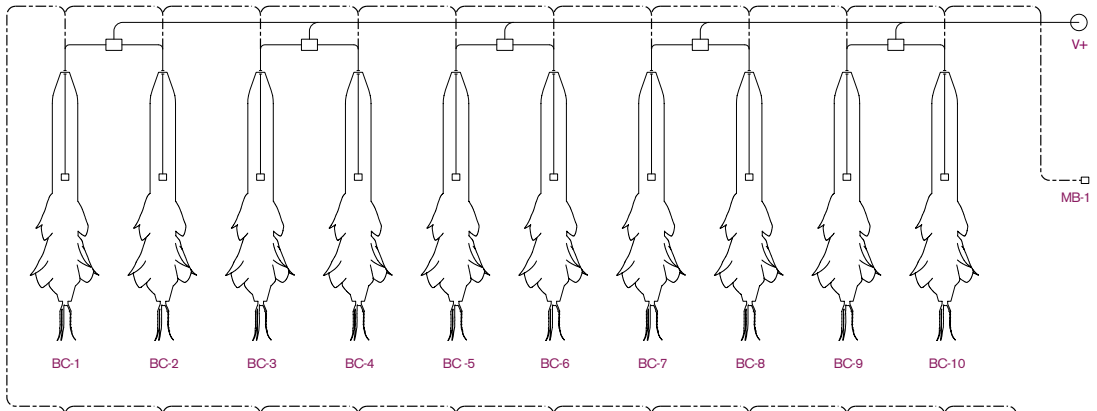
2 Visualization of programmed series of
   motions initiated by occupants within
   Hylozoic Ground.

This is the case for screen-based works, which rely on computer hardware and electronic storage. But it is even more true of kinetic and interactive non-screen-based works, like the Hylozoic environments, because of their reliance on numerous physical components as well as distributed and embedded systems. New paradigms are being developed for curating and documenting these works, often termed 'variable media,' or 'new media.' Examples include Richard Rinehart's *Media Art Notation System* (MANS), or Jon Ippolito's *Variable Media Questionnaire*, which spawned the Variable Media Network (www.variablemedia.net) in partnership with the Daniel Langlois Foundation. Enriching discussions are taking place in forums like CRUMB (Curatorial Resource for Upstart Media Bliss; www.crumbweb.org).

A central parameter in the assessment of 'good' interactive art is the extent to which the interaction allows access to the experience of the artist's intent. The *potential* for interaction, particularly computer-mediated interaction, is so great that the designer can be tempted to pursue something just because it is possible. The creation then becomes slave to the technology, rather than the technology service the concept, and the experience of 'using the interface' obscures the work. This is not to say the technology must be transparent, or that the experience of the interface cannot itself be a part of the artist's intent. But the 'interaction layer' should not be so thick that it becomes impossible to penetrate beyond to the 'conceptual layer.' In such cases, even if the user leaves feeling satisfied with their experience, the work has failed to effectively convey the artist's intent.

the arduino project

Within the Hylozoic environment, the thin interaction layer is implemented using low-level embedded electronics and distributed sensing and actuation systems, powered by the Arduino platform. Arduino is an open-source physical computing platform that was created to make tools for software-controlled interactivity accessible to non-specialists. The Arduino microcontroller board can read sensors, make simple decisions, and control devices. This palm-sized computing platform is the product of an open-source community project that began with a small group of hardware developers giving work-shops, and that now numbers many tens of thousands of international users that co-operate in developing specialized applications. The first developers of Arduino—Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino,

V+

MB-1

BC-1   BC-2   BC-3   BC-4   BC-5   BC-6   BC-7   BC-8   BC-9   BC-10

V+

BC-11   BC-12   BC-13   BC-14   BC-15   BC-16   BC-17   BC-18   BC-19   BC-20

V+

CC-1   CC-2   CC-3   CC-4   CC-5   CC-6

AIR

CC-7   CC-8   CC-9   CC-10   CC-11   CC-12

SC-1   SC-2   SC-3   SC-4   SC-5

V+

FC-1   FC-2   FC-3   FC-4   FC-5   FCD-1   FCD-2   W-1

V+

FC-6   FC-7   FC-8   FC-9   FC-10   FCD-3   FCD-4   FCD-5

David Mellis, and Nicholas Zambetti—ran workshops demonstrating assembly of the devices, and gave copies of the board away to stimulate development. A community of developers and users now provides co-operative support, and the programming environment and documentation is written with the neophyte in mind. To date, the Arduino community has created myriad documents describing how to extend and interface Arduino with different systems. Examples include MaxStream's inexpensive and compact XBee RF wireless transceivers; Bluetooth-enabled mobile phones, using the Arduino BT extended board; LCD displays; and Cycling 74's Max/MSP/Jitter graphical scripting environment.

The distributed nature of the interactive environments in the Hylozoic series and the group behaviour that emerges relate strongly to the open-source ethos of the Arduino project. Individual occupants move within the Hylozoic environment as they would through a dense forest thicket. Local sensors embedded throughout the environment signal the presence of occupants to controlling microprocessors, and motion ripples through the system in response.

Dozens of microprocessors, each controlling a series of sensors and actuators, collaborate indirectly to create emergent reactions akin to the composite motion of a crowd. Visitors move freely amidst hundreds of actuated kinetic devices within this interactive environment, tracked by many dozens of sensors organized in 'neighbourhoods' that exchange signals in chains of reflexive responses. The installation is designed as a flexible, accretive kit of interlinking components, organized by basic geometries and connection systems. Like the open source Arduino project itself, variations are produced by numerous individuals during the assembly of the piece. At all levels—assembly, function, and experience—the result expresses the turbulent chorus of a collective accretion.
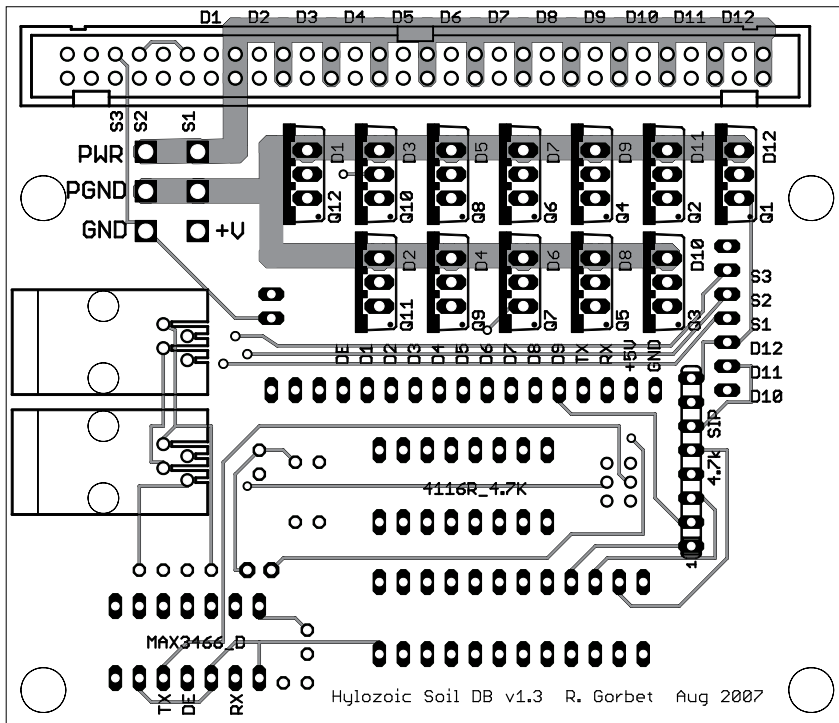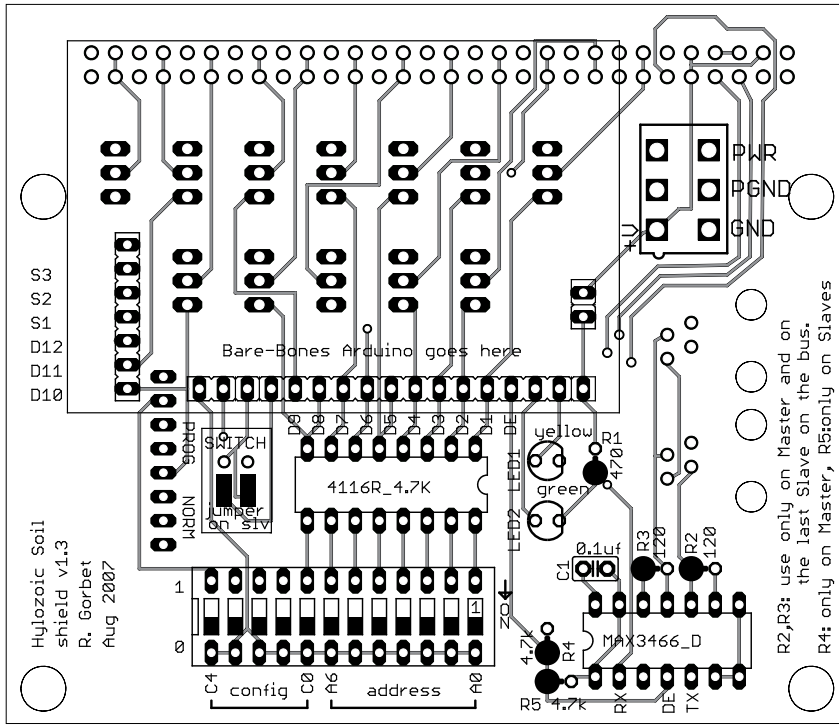
the hylozoic control system

The control system that was developed for active functions within the Hylozoic environment deserves mention. The micro-controller used in this Arduino platform is the 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. Software is custom written in
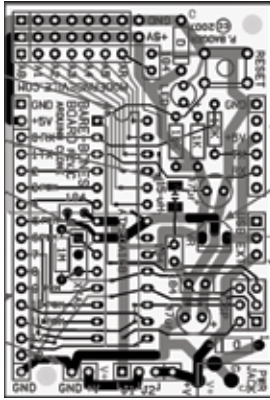
facing page

3 Global Systems Diagram showing all actuated elements, communications routing, power distribution and air supply routing, **Hylozoic Ground**.

BC   Breathing Column
SC   Swallowing Column
CC   Cricket Cluster
FC   Filter Cluster
FCD Filter Cluster Drone
W   Whisker Cluster
MB   Masterboard
AIR Main Air Supply
V+   Main Power Supply

Top board (silkscreen/layout):

PWR
PGND
GND

+V

S3
S2
S1
D12
D11
D10

Bare-Bones Arduino goes here

Hylozoic Soil
shield v1.3
R. Gorbet
Aug 2007

PROG

SWITCH

NORM

jumper
on slv

1

0

C4   config   C0   A6   address   A0

4116R_4.7K

yellow   R1
470
green

LED2 LED1 DE

0.1uf   R3   R2
C1   120   120

ZO

MAX3466_D

4.7   R4

R5 4.7k   RX   DE   TX

R2,R3: use only on Master and on
the last Slave on the bus.
R4: only on Master, R5 only on Slaves

Bottom board (layout):

D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12

S3 S2 S1

PWR

PGND

GND   +V

D1 D3 D5 D7 D9 D11 D12
D12 D10 D8 D6 D4 D2 D1
Q12 Q10 Q8 Q6 Q4 Q2 Q1

D2 D4 D6 D8 D10
D6 D8 D10
Q11 Q9 Q7 Q5 Q3

S3
S2
S1
D12
D11
D10

DE D1 D2 D4 D5 D6 D7 D8 D9 TX RX +5V GND

SIP

4.7k

4116R_4.7K

1

MAX3466_D

TX DE RX

Hylozoic Soil DB v1.3 R. Gorbet Aug 2007

a high-level language on a personal computer and programmed into the microcontroller by connecting the Arduino board to the computer's standard USB port.

The version of the Arduino hardware used for the Hylozoic series is the Bare-Bones Board, developed by Paul Badger.[4] This inexpensive implementation of the platform has a small forty-by-sixty-millimetre footprint, and is provided either fully assembled or in kit form. The board includes components for power regulation, timing, and external digital inputs and outputs that can control a range of interactive devices. A custom 'daughterboard' (or 'shield') was developed by the author to provide 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 one amp per circuit and voltages of up to fifty 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 software modes to control board behaviour. The communication interface converts serial communication signals from the Arduino and supports high-speed distribution to a network of boards using the RS485 standard. The daughterboard also provides a sixty-pin ribbon cable interface for connecting actuators and sensing devices. There is a two-channel power connector to distribute high currents to actuators as well as a lower current 'electronics' supply.

actuation

The Hylozoic environment includes several kinds of actuated elements: breathing pores, sensor lashes, filters, crickets, and swallowing actuated by shape-memory alloy (SMA) muscle wires; whisker elements driven by small direct-current motors; and a range of lights including high-powered LED clusters and miniature signalling lights. The devices are designed to operate at five volts and are interchangeable in the control harness, allowing flexibility in their spatial distribution throughout the meshwork.

Under software control, the output drive channels switch current from the high current five-volt supply to each of the individual actuator elements
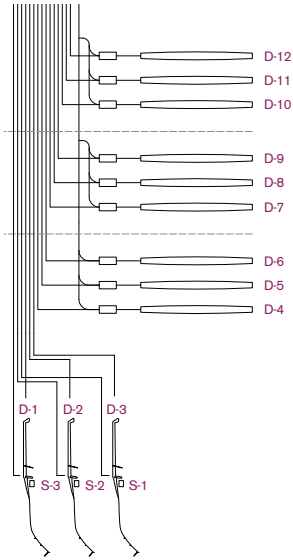
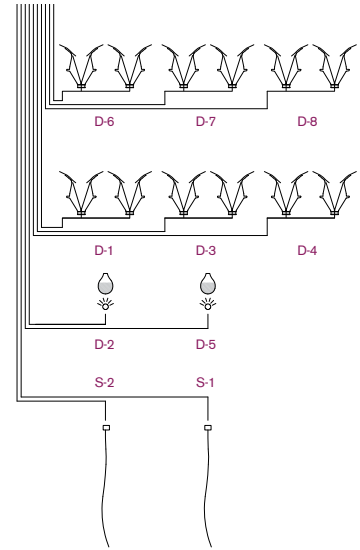REVEALING THE HYLOZOIC GROUND INTERACTION LAYER
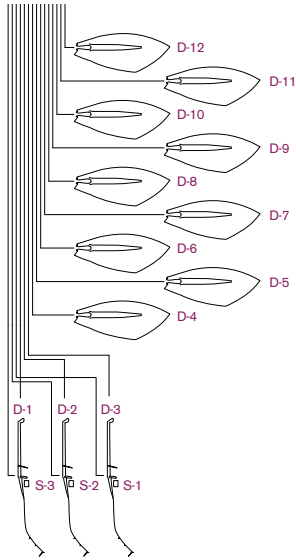
6 Breathing Column

Output: 9 Breathing Pores,
3 Sensor Lash Actuators
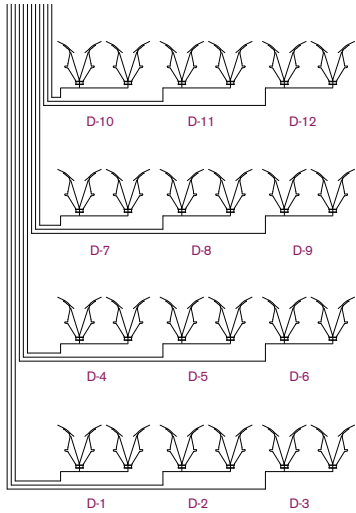Input: 3 Proximity Sensors

7 Swallowing Column

Output: 9 SMA Valves (Air Muscles),
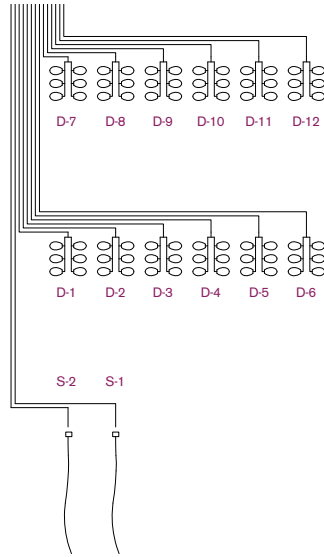3 Sensor Lash Actuators
Input: 3 Proximity Sensors

8 Filter Cluster

Output: 6 Filter Pairs,
2 Burst LED Triggers (PWM)
Input: 2 Whisker Capacitance Sensors

using a transistor switch. The SMA-actuated pores and lashes 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 half-inch contraction that occurs in each wire and translates this into a curling motion. Filters and crickets use several shorter lengths of Flexinol wire in series to maintain the same electrical characteristic as pores and lashes but provide more subtle kinetic response. Several proximally-located swallowing actuators use SMA-powered pneumatic valves to control air pressure in custom air muscles, coordinating their action to produce a peristaltic motion in the surrounding meshwork. The whisker elements are composed of flexible wound wire strings extending from the shaft of a small three-pole motor. In combination with 150-ohm current-limiting resistors, yellow LED lights are configured for the five-volt power supply to create visual feedback. These LED lights add a signalling layer to the Hylozoic ground environment, offering a visual map of the system response.

ROB GORBET

D-10 D-11 D-12

D-7 D-8 D-9

D-4 D-5 D-6

D-1 D-2 D-3

D-7 D-8 D-9 D-10 D-11 D-12

D-1 D-2 D-3 D-4 D-5 D-6

S-2 S-1

S-1

D-1 D-2 D-3 D-4 D-5 D-6 D-7 D-8 D-9 D-10 D-11 D-12

9   Filter Cluster Drone

Output: 12 Filter Pairs
Input: Neighbouring Behavior

10   Cricket Cluster

Output: 12 Cricket Sets
Input: 2 Whisker Capacitance Sensors
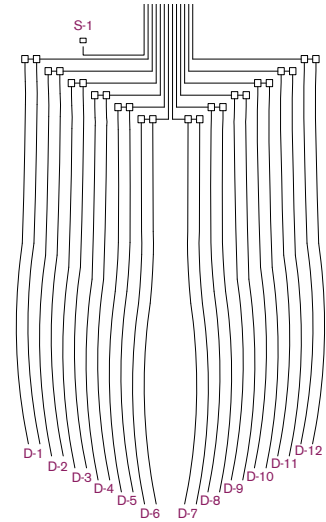
11   Whisker Cluster

Output: 12 Motor Driven Whisker Pairs
Input: 1 Proximity Sensor

sensing

6 - 11 Power and communications
between actuated clusters of
mechanisms on each Arduino
microprocessor.

Each daughterboard accommodates up to three analog sensors. Infrared proximity sensors with varying detection ranges provide feedback that allows the sculpture to respond to occupant motion. Powered by the five-volt electronics supply, the sensors emit an infrared signal and receive reflections of the signal from nearby objects, registering the distance of the reflecting surface and feeding that information back to an input on the Arduino board. A second type of capacitance-based sensor signals the approach and touch of an occupant through perturbations in electric fields generated by the occupants' bodies themselves, much like the sensory nerve endings of the epidermis.

communication and programming

The daughterboard also contains a communication layer which translates raw serial data from the Arduino to the RS485 communication standard. Jacks connect the boards to a 'full-duplex, differential multi-drop' bus. A full-duplex implementation uses two pairs of wires: one pair for incoming information and the other for outgoing data, allowing for simultaneous communication in both directions along the bus. Each board constitutes one 'drop' of the multi-drop system, and communicates with the others via a single board, which assumes the role of 'bus controller.'

RS485 is a differential standard, wherein information is transferred on pairs of wires that carry differing voltages. Bit values are detected by measuring the difference in voltage on the paired wires. Together with the use of twisted-pair cabling, this scheme makes the system less prone to communication errors induced by electrical noise. The Maxim MAX3466 transceiver chip used in the daughterboard allows up to one hundred and twenty-eight boards to communicate. Since there is the potential for multiple devices to 'drive' the shared bus lines, bus conflicts can occur; this typically results in garbled information transmission at best, and can pose a serious threat to the hardware. Therefore, the MAX3466 chip includes a pin, controlled by one of the Arduino's digital outputs, which allows the microcontroller to effectively turn off the driver circuitry.

In addition to the bus transceivers, the daughterboard contains hardware which permits simultaneous 'batch' programming of all the devices connected to the bus. Normally, a device is programmed by connecting it to a computer's USB port, then resetting it before running a software tool on the computer to download code to the Arduino. When the Arduino is reset, a special program called a 'bootloader' executes for a few seconds, listening for incoming information on the serial port. By setting a switch on the bus controller board to 'program' mode, any board connected to the bus will see messages sent by the computer to the bus controller. If the boards are all reset just prior to downloading new code from the computer, the bus controller will act as a proxy in the exchange, and every board will receive the new code. The bus controller switch is then reset to normal mode and it resumes control of the bus.

multiple layers of responsiveness

Combined with the bus architecture described above, the Arduino system provides an inexpensive platform for experimentation with distributed intelligence and emergent behaviour in a physical environment. For example, each local board in the Hylozoic environment can produce several layers of response to a visitor's presence within the mesh.

As a local response, any board which registers change in its sensor status immediately activates a reflex device, reinforcing the connection between the actions of the visitor and the sculpture. Reflex responses are followed by slightly delayed and more coordinated chains of reactions by devices connected to the triggered board. Additionally, the board informs the rest of the environment, via the bus controller, that it has detected a visitor. Boards are programmed to respond to messages from their spatial neighbours, setting up larger but more muted chains of reaction. A third layer of behavioural control is orchestrated by the bus controller: Since it relays all messages, it is aware of the general level of activity within the mesh. It can therefore exercise some control over system-wide behaviour by asking the mesh to set up a general low-level behaviour if things are too quiet, or to quiet down if activity is excessive.

The Hylozoic series is a body of work that has been gradually transitioning from individual figures, composed of complex hybrid sculptural assemblies, towards immersive architectural environments that behave like highly mobile crowds of interlinked individuals acting in chorus. The most recent generations of this work employ active sensing and actuator mechanisms in pursuit of reflexive, kinetic architectural environments. Hylozoic Ground, as exhibited in Venice, builds upon previous generations by developing a decentralized structure where much of the system is distributed and extensible, based on localized intelligence.

The electronics in the Hylozoic environments—the sensors, controllers, actuators, power, and communication systems—are expressly revealed, a visible reminder of the sentient nature of the environment. But the interactions are specifically designed to be subtle, reflexive, and natural. They require no cognitive overhead and leave the visitor to the environment, free to wonder at the possibilities for the future.