Chapter 5.

Related Work

This chapter provides a detailed description of relevant work from visual art and design practices, human computer interface and electronic musical instruments. Because the portfolio of projects presented in this thesis falls into many categories, like fashions, jewelry and computer interface, it would be possible to present an unlimited amount of related work from many various fields. I have attempted to pick work from the visual arts and design that is related to the portfolio work through its process and materials. Some of this work involves computing materials and some does not. I have also shown electronic musical instruments, because I believe, they are excellent models for any expressive, computing and interactive object.

Robotics as Computational Assemblage

As previously discussed, additive processes are ideal for manipulating the current physical materials of computing technology. In fact, that is how most computing objects are made; they are a group of mechanically attached buttons, chips, circuits and displays. Consequently, most three-dimensional works of computer art, or sculpture, are what is called in the field of sculpture, an *assemblage*.

An *assemblage* is the result of an additive process that juxtaposes many disparate materials or found objects to create an artifact with new meaning. In the 20th century, an *assemblage* was radical both formally, and within artistic practices that were more content driven. In Futurism, Surrealism and Dadaism, *assemblage* was considered artistically radical because it allowed artists to create new content and social messages. Raoul Hausman's *Mechanical Head* is an early example of the reassembly of found materials for the purpose of dramatically changing their meaning. Marcel Duchamp used industrially produced objects he called *ready-mades* to draw into question both the assumption that sculpture was the hand-made and the assumption that an work of art was the result of personal aesthetic investigation. Duchamp's *Fountain* placed a urinal, an industrially produced object, on the wall as art. This was a radical move, and dramatically changed the meaning of the art object, by drawing into question what it meant to be a hand–made object an industrial age.[1] Today, sculptural works in conceptual arts practice use materials that are chosen for their symbolic meaning, like the use of raw meat in Jana Sterbak's *Meat Dress*.

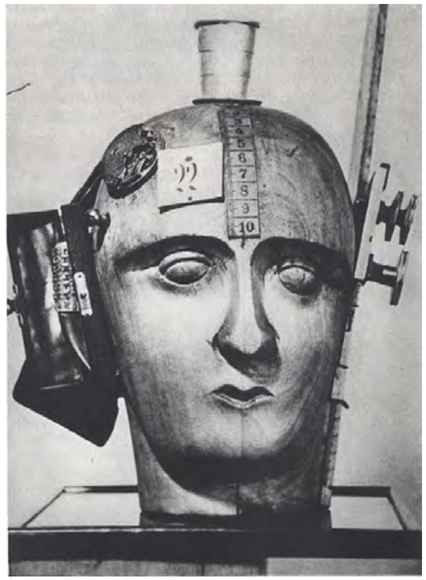

Figure 5.1 Raoul Hausmann, "Mechanical Head", 1919-20.

[1] Krauss, Rosalind E., *Forms of the Readymade: Duchamp and Brancusi*, Passages in Modern Sculpture, Cambridge, MA, MIT Press, (1977).

Looked at from a more formal point of view, *assemblage* has also been seen as radical. Until the 20th century certain materials simply were not seen as appropriate for sculpture; they were seen as poor materials. But the freedom of *assemblage* and working with poor materials radically changed 20th century art. Picasso used *assemblages* made from paper and cardboard to create many of truly sculptural works. The acceptance of *assemblage* has also encouraged artists in the 20th century to be resourceful; to work from any materials that are at hand and that meet their artistic needs. For instance, Louise Borgeois chose the wooden and other various materials of her large assemblages as a result the unavailability of steel and bronze during WWII.

Fine artists working with physical computing materials have also shown a real resourcefulness, creating a myriad of additive objects, or *assemblages* from found or purchased computing materials. Usually, these *assemblages* have tended toward the robotic. In some cases, artists have stuck together pieces of old computers and transformed them into new mechanical entities. In fact, the scope of robotic artworks has been well documented in Ken Goldberg's recent book, *Robot in the Garden.*[2]

Tim Anderson, Painting Machines

Tim Anderson's painting machines (from the early 1990's) relied on the reassembly of old junk computers and printers into robotic painters. These painting

[2] Goldberg, Ken, (ed.), Robot in the Garden, Cambridge, MA, MIT Press, (2000).

machines created abstract expressionist paintings on canvas. In this work, Tim Anderson completely re-purposed computing technology by reassembling the parts of old printers and PC's into his abstract expressionist painting machines. These works were particularly successful because they re-purposed pieces of existing printers and computers, and turned them into *art* making machines. The motion (or dynamic display) of the robotic painting machines themselves was often more expressive and beautiful then the paintings that they created. I have seen many of these machines personally, and can attest to the fact that their motion is truly beautiful and highly expressive.

Stelarc, Robotics and the Body

Australian born performance artist, Stelarc has wired his body to a whole series of robotic devices, including his piece the *Third Arm.*[3] In this piece Stelarc sets up a feedback loop between a third robotic arm that is connected to his real right arm, the muscles of his legs and the muscles of his left arm. Stelarc uses the motors of the arm for audio output as an intentional part of his performance with this robotic device. Stelarc's work has always been of interest to me because it questioned the limits of bodies and "the self" and the role of technology as an extension of the self. In this work, it is the motion of the body and its relation to the motion of the robotic arm that makes for an intriguing performance and juxtaposition of the mechanical to the natural.

[3] Stelarc, homepage, http://www.stelarc.va.com.au/third/third.html, World Wide Web, (2001).

Figure 5.2 Stelarc, *Third Arm.*

Ken Goldberg, *Telegarden*[4]

Robotic works like Ken Goldberg's *Painting Machines*, and his *Telegarden* are excellent examples of robotic, computing sculpture. Like much socially motivated assemblage from the early 20th century, these robotic art works do re-contextualize computing technology. Ken Goldberg's *Telegarden* juxtaposes computing technology, robotics, and the Internet, with nature. This robotic garden allows a web-based community of gardeners to remotely plant and tend a real garden, through a single, central robot. What I enjoy about this piece is the relationship of the strong and industrial robot, to the planting and care of the tender plants. When the robot moves it seems frightening and dangerous. The robot makes for a strange and jarring "avatar" for the human community on the other end of the computer.

Figure 5.3 Ken Goldberg, *Telegarden,* 1995-ongoing.

Plastic Manipulation vs. Assemblage

All of the previously described works use mechanical motion to *display dynamic reaction*[5]. Creating these works involved a direct, hands-on, *additive* process. This direct process *did* lead to an understanding of physical materials, computation and robotic motion. So how are additive hands-on works different plastic ones? Why doesn't robotic sculpture fulfill the need for the direct hands-on manipulation of computational materials that leads to an artistic understanding of physical form, materials and computation? Once

[4] Goldberg, Ken, homepage, http://www.ieor.berkeley.edu/~goldberg/, World Wide Web, (2001).
[5] See properties of computational objects, Chapter 3.

assemblage works like Louise Borgeois' were considered radical. Critics wondered if an assembly of found parts could be truly "sculptural" in the *formal* sense. Today, these works are accepted *formally* as both **S**culpture and **S**culptural. Mechanical works like Calder's circus characters have become classic sculptural items in the 20th century. So why can't robots, mechanical assemblages of computer parts, be truly sculptural? Certainly, they are. And many robots *are* becoming more and more human-like in their form. So who cares if there can be no plastic or clay-like manipulation of active computing materials?

I believe that just as the assemblage of prefabricated materials revolutionized the traditional world of sculpture (which had previously relied on plastic manipulation of raw materials like clay and stone), so will the plastic manipulation of active computing materials revolutionize the form, function and ultimately, symbolic *meaning* of computing objects. Until now, computing designers and artists who wished to work with physical computing materials in a *plastic*, direct, and sculptural manner, had to work with materials that are *inactive* and *non-computing*.

Dave Small and Tom White, *Stream of Conciousness*[6]

David Smalls' interactive garden, *Stream of Consciousness* uses non-computing, *plastic* materials

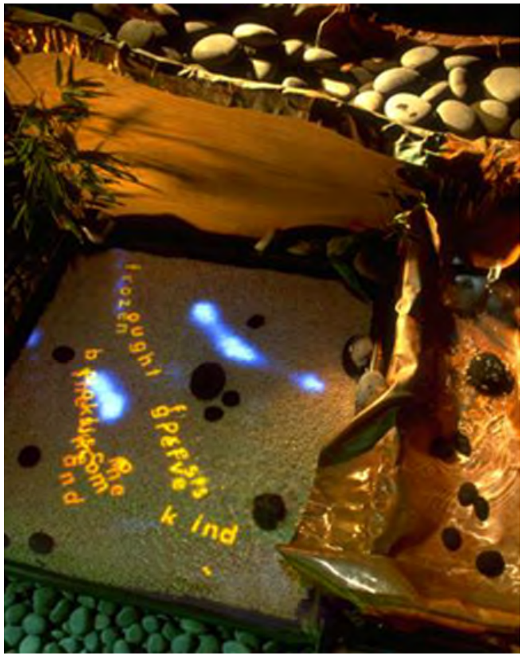

Figure 5.4 Dave Small, Tom White, *Stream of Conciousness,* 1997, with shaped copper and stones.

[6]Small, D., White, T., *An Interactive Poetic Garden*, (short paper), Proceedings of Conference on Human Factors in Computing Systems, (CHI 1998), Los Angeles, ACM Press, (1998) pp. 303-304.

in a sculptural manner to create an interesting backdrop for his interactive software images. But these materials remain separate from the computational activity of the piece, they are just a back drop or screen for the projected text. But imagine what might happen if the shaping of the copper in this *Interactive Garden* had some real effect in software, or some effect on what words were seen or displayed. The material would then be sculpturally plastic and computationally active, leading to artistic possibilities we cannot yet imagine.

Meaning and Materials in Sculpture

The possibility of *plastically* using active physical computing materials that have unique *sensual* properties will also truly change the possible form, sensual properties and therefore *meaning* of computers. Artistic choice of materials and the effect they can have on form and meaning is what is essential here. There is a certain type transformation of meaning through the plastic shaping of diverse physical materials that is not possible with the current physical materials of computing. The following examples of both Joseph Beuy’s and Merit Oppenhiem’s work, demonstrate the relationship between meaning and materials that is possible when a range of materials can be plastically used by artists.

Joseph Beuys, (1921-1986) Materials Before Form

One of the main themes of artist Joseph Beuys' work was to put materials and before form.[7] His works used non-traditional, "indeterminate, raw materials to suggest energy potential, investigate alchemical meaning and stimulate senses like smell and touch. These 'poor' materials included felt, fat dead animals, copper, sulphur, honey blood and bones"[8] The alchemical language of these materials recognizes that "felt is an excellent insulator, just as beeswax is a good insulator but poor conductor of heat, or that copper is an excellent conductor of heat and electricity."[9] When Beuys juxtaposed these materials, with different properties, he suggested their energy potential. By placing these materials in "determinate" containers, like vats or jars, or in physical configurations with energy potential, (such as a wedge), Beuys suggested and referred to the power of sculpture to transform entropic materials into shapes with mechanically stored, potential energy. In *Chair with Fat,* the entropic fat, a material with stored energy is shaped into a wedge. The wedge shape imparts additional energy to the material. Beuys' "Fond III" (Figure 2.8) juxtaposes copper and felt. The copper rests on nine piles of felt. This piece juxtaposes two materials with antithetical energy properties, copper (conductor), and felt (insulator). The placement of the heavy copper sheets

Figure 5.5 Joseph Beuys, *Chair with Fat,* 1963.

Figure 5.6 Joseph Beuys, *Gelatin Object*, 1968, gelatin, wax and part of a transformer.

[7] Borer, Alain, The Essential Joseph Beuys, Cambridge, MA, MIT Press, (1997).
[8] Ibid.
[9] Ibid.

high on top of the soft, stacked felt, physically and structurally reinforces the energy potential of materials.

Beuys' use of materials for their alchemical properties and differences in energy potential has always been a great influence on my work. My interest in the electrical and material properties of computing materials, like silicon and metal, finds much of its roots in Beuys. But unlike Beuys, I have been interested in exploring the energy potential of computing materials not just symbolically, but *functionally*. The desire to understand and functionally use the different properties of computing materials has led me to an investigation of material science.

In *Infiltration Homogenous for Grand Piano* and *Fond III*, Beuys uses the contradictory properties of materials to create a symbolic piece about energy potential. In I*nfiltrations*, the energy of a piano, (an acoustic resonator), is contained by a wrapping of felt (an acoustic insulator). In *Fond III,* stacks of electrically insulating felt are topped with highly conductive copper plates to emphasize energy potential. This work inspired me to think about turning textiles, which are acoustic, and electrical insulators, into electrically and musically active materials, and to create both electronic textile objects and musical textile objects.

Merit Oppenheim, *Fur Lined Tea Cup*

Surrealism has always sought to recontextualize meaning, to make the ordinary strange through the juxtaposition and assemblage of incongruous objects

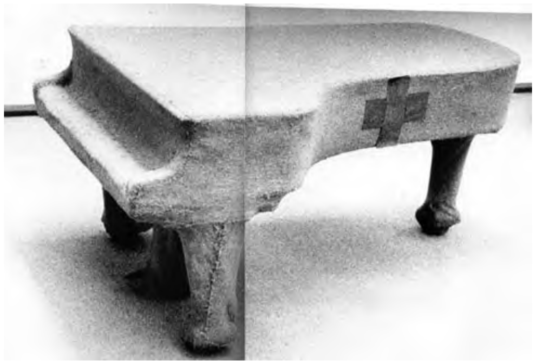

Figure 5.7 Joseph Beuys, "Infiltration Homogenous for Grand Piano", 1966. A piano, wrapped in felt.

and materials. This juxtaposition has sought to combine reality with the world of dreams.

> I believe in the future transmutation of those two seemingly contradictory states, dream and reality, into a sort of absolute reality, of surreality, so to speak. I am looking forward to its consummation, certain that I shall never share in it, but death would matter little to me could I but taste the joy it will yield ultimately.[10] (Andre Breton)

In 1936, Merit Oppenheim covered a teacup with fur. The result is the quintessential Surrealistic object.

> Oppenheim had decorated a bracelet with fur, and Picasso jokingly commented that fur could cover anything. Her response was another joke: a fur-covered cup, saucer, and spoon, *Le Déjeuner en Fourrure,* its official name.[11]

By covering a teacup with fur, Merit Oppenheim created an entirely new object, whose meaning does not derive simply from its functionality. Her *Fur Lined Tea Cup* triggers unexpected, subconscious feelings in the viewer, perhaps sexual feelings, or feelings of desire. Her use of antithetical materials asks us to rethink our preconceived ideas about reality.

This use of materials to transform an ordinary object into something evocative inspired me to believe that transforming the computer *materially* could have a similar affect. Antithetical materials could bring new

Figure 5.8 Merit Oppenheim's *Fur-lined Tea Cup.*

[10] Breton, Andre, *What is Surrealism*, Selected Writings, NY, Monad, (1978).
[11] Barlow, Margaret, Women Artists, Levin, Hugh Lauter Associates, (1997).

and other meaning and purpose to computers, extending the function of technology beyond the limits of practical purpose.

Symbolic Materials in Practical and Interactive Computing Objects

Just as materials can transform meaning, and ultimately function, in sculptural practices, so can they in computing design. Designing with antithetical computing materials, like textiles and rubber can bring new meaning and purpose to computers. Sculptors have achieved this by having access to, and adopting a diverse range of material that are unusual and outside established sculptural materials. Computer artists might take a similarly aggressive tack toward this type of material use. They might cover a cell phone with honey to transform its meaning. I suppose within the rarefied space of the gallery this might work. But computing objects are interactive, often demanding that people touch them, and that they are functional and durable. In fact, if computing objects don't work, they are not successful. Materials that relatively are durable, can become part of everyday life, and artistically meaningful, are then, essential for artists and designers who want to transform physical computing and interactive technology. And just covering a cell phone with honey contributes nothing toward the investigation of the expressive language of physical form and computation. Materials that are *plastic*, symbolically diverse and computationally active will allow for this type of investigation.

Product and Industrial Design

Creating a commercial computing object or product is almost an entirely additive process, (as opposed to *plastic* process), which requires the integration of many prefabricated parts, like input sensors, displays, and/or speakers into a plastic shell. It is this plastic shell, which most industrial and product designers get to plastically, albeit remotely, shape. The Palm Pilot is shaped to fit in your hand. Cell phones are shaped to fit in your hand and be spoken into. Many mice and keypads have been designed to be more ergonomic, fitting into a user's hand more comfortably. With the current onslaught of Repetitive Stress Syndrome, creating a variety of ergonomic physical computing devices has been essential. In general, all these objects are the result of a process that is materially remote and CAD-driven.

It is important to recognize that, in general, the additive design process of industrial and product design cannot be equated with sculptural *assemblage*. In sculptural assemblage, objects and materials are purposefully taken out of context to create new meaning. But there is no such recontextualization in commercial computational objects or consumer electronic devices. These kinds of computational objects contain elements that are *intended and designed* to become part of a single object. For example, the standard PC is a mix and match of separate prefabricated parts. But this construction of pieces does nothing to recontextualize them or challenge their established meaning or function. Thus, in traditional industrial design and product design, an assembled group of standard computational materials does not behave in an active symbolic manner. It simply repeats and reinforces the expected meaning and role of computers and technology.

Apple Computers

Recently, industrial design has begun to transform the plastic shells of computers and other computing devices into more aesthetic and stylishly designed items. The new Apple computers and many of today's more funky pagers and PDA's are great examples of this. This aesthetic emphasis involves changing the shape, color and transparency of the plastic housing. Apple's in house design team achieved the look of the iMac and iBook by creating elegant new plastics and even designing the shape of certain circuit boards to be visually appealing inside the transparent housing.[12] While this approach has been truly innovative in the design of the personal computer, a careful look at the new iBook shows the limitations of using the plastic housing to attempt to transform square, prefabricated parts into rounded, sculptural objects. In order to accommodate the size of the screen and be curvaceous, the laptop has had to dramatically increase in size.[13] Mac designers have also been very clever about disguising generic PC parts, like the CD-rom drive, behind a more aesthetic and rounded exterior. This process has also led to an increase in size.

Figure 5.9 iMac, 2000.

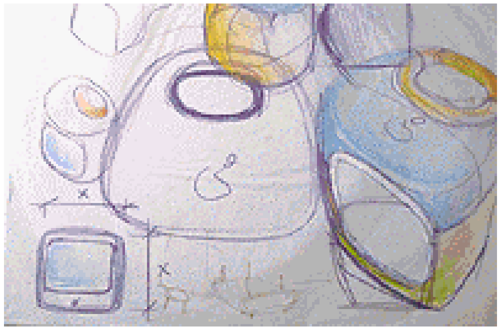

Figure 5.10 Sketches of new Apple computers, iMac design team.

[12] Hirasuna, Delphine, *Sorry No Beige, Apple Interview*, Apple Website, World Wide Web, (2001).
[13] See Chapter 4, for a detailed description of this phenomena.

Durrell Bishop

Product design is often scenario driven, based on stories about the future of technology. These scenarios are often then used to drive the design for physical prototypes. Through scenarios, visionary designers like Durrell Bishop have suggested through many wonderful ways that computer technology can become more three-dimensionally interesting and functional (including his classic *Marble Answering Machine*[14]). Bishop has also created working prototypes of his scenarios with the active computing materials. In fact, he spends an enormous amount of time working with physical materials, as in his working prototype of the *Marble Answering Machine* incorporated into a broader intelligent environment,[15] which allowed users to associate pieces of audio information with different physical objects. In this prototype, Bishop used resistive IDs and other computationally active materials to actualize his idea. This project actively worked to incorporate the functional materials of computing technology, like the resistive ID's and new materials like wood. He even uses the conductive properties of paper clips to read their resistive ID through DC current.

At the same time this project demonstrates how existing computing materials encourage scenario driven research and can limit the actual making of physical objects. The idea of these digitally augmented objects was excellent, realizing them, however,

Figure 5.11 Durrell Bishop, stills.

[14] Bishop, D., Marble Answering Machine, Director Animation, (1992).
[15] Bishop, D., Still Images, reprinted with his permission, (1994).

involved working with limited materials the led to a sort of baroque interaction with the objects. For his *real* system to read the resistive ID's of objects, the user had to go through an elaborate physical process of connecting different objects to a sort of magical ID wand. This process became almost an elaborate ritual that was not present in the original director based scenario. If his physical computing materials had allowed him to directly sketch the way his sketchpad did, this problem might not have occurred. Physical computing materials that are part of the sketching and idea process can help overcome the scenario/working prototype separation that often occurs when designing computing objects.

Bishop himself is fully aware of the limits of physical computing materials, and at a Media Lab colloquium (October 27, 1999), he referred to the limiting, generic, palette of materials he faces as a designer of computing objects. He presented a palette that was a demoralizing bunch of buttons and screens. Bishop has faced this palette aggressively. One successful way that he has faced these materials is to accept them, and then use them in entirely unusual ways and create innovative objects with them. In fact, he has acknowledged the importance of materials in his work *Monitor as Material* (1996, with Michael Field). This work uses a screen to "enhance and define the functions of the whole object, like cartridges in a

Figure 5.12 Durrell Bishop, Michael Field, *Monitor as Material*, 1996.

Gameboy."[16] Bishop himself says of the square monitor:

> "*Monitor As Material* cleverly demonstrates that the prevailing screen aesthetic results as much from cultural convention as any intrinsic technical properties." [17]

"Monitor as Material" tries to change the role of the monitor as material, not by changing its physical properties, but by changing its function.

While I agree with Bishop that there is a strong pictorial tradition (painting, photography, and film), which has culturally directed the artistic development of computing technology into the realm of the square and the screen, I also believe that the technological limitations of physical computing technology have severely limited their development as an artistic medium. Changing those materials, will I believe, lead to a more in depth artistic exploration of physical form and computation. Thus in many ways, what separates my work from Bishop's is the desire to change the physical materials of computers, rather than re-appropriate or re-purpose them.

[16] Abrahms, R., Adventures in Tangible Computing, the Work of Interaction Designer, Durrell Bishop, in Context, *Masters Thesis for the Royal College of Art*, (1999).
[17] Owen, W., *Monitor as Material*, Expo supplement, ID Magazine, New York, August, (1996) taken from above.

Human Computer Interface and Tangible Computing

Hiroshi Ishii, Various Works

Hiroshii Ishii's desire to make computers *tangible* has led to innumerable fascinating, experiments in tangible computing[18]. While human computer interface research *usually* focuses on making computers more useable, Ishii's research also displays a strong desire to make computers more physically and tactilely aesthetic. A few projects from his Tangible Media agenda stand out as *materially* transforming computing technology. *inTouch*[19] (Scott Brave, Victor Su, Phil Frei, Rujira Hongladaromp, Andrew Dahley, and Hiroshi Ishii) allowed people to tactilely communicate through two computer controlled sets of rollers. This project, which required people to rub their hands over it, was made of wood, and gave people are far different tactile experience of computing technology than the usual plastic of computers. The groups' paper *Pinwheels* (Sandia Ren, Phil Frei, Seye Ojumu, Rujira Hongladaromp and Hiroshi Ishii) took computing technology into the realm of the materially ephemeral and delicate. Ali Mazalek, Jay Lee, and Hiroshi Ishii also created *Music Bottles*, which allow people to turn

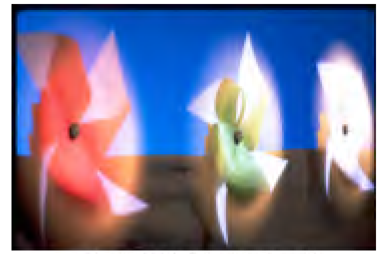

photo: Webb Chappell

Figure 5. 13 Sandia Ren, Phil Frei, Seye Ojumu, Rujira Hongladaromp and Hiroshi Ishii, *Pinwheels,* 1999.

Figure 5.14 Scott Brave, Victor Su, Phil Frei, Rujira Hongladaromp, Andrew Dahley, and Hiroshi Ishii, *inTouch,* 1997.

[18] Ishii, H. and Ullmer, B., *Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms,* Proceedings of Conference on Human Factors in Computing Systems, (CHI 1997), Atlanta, ACM Press, (1997) pp. 234-241.

[19] Brave, S. and Dahley, A**.,** *inTouch: A Medium for Haptic Interpersonal Communication,* (short paper), *Extended Abstracts of Conference on Human Factors in Computing Systems*, (CHI 1997), Atlanta, ACM Press, (1997) pp. 363-364.

off and on musical voices by handling glass bottles and removing their stoppers. All of these projects use highly aesthetic and transformative *housing materials* to give computing technology a new tactile identity.

Brygg Ullmer, *Strata*

More recently, Brygg Ullmer's work in *Strata*[20] starts to incorporate computing functionality directly into his design materials. Ullmer laser cuts acrylic to create both shapes and cavities for electronic circuitry and components, which he then uses to create a model of a building. Ullmer describes an early version of Strata as taking the "form of a five-layer, translucent acrylic model woven with embedded lights, sensors, and computation."[21] Using the laser cutter lets Ullmer sketch and create, both electronic "place holders", and shapes, through the same manufacturing process. The results of this process have led to unusual aesthetic items, like the curvaceous electronic base for *Strata* (Figure 5,15). In *Strata*, Ullmer is starting to create acrylic sheet material with electronics or computational functionality built right in. While this material is still hard plastic, it certainly suggests a manufacturing and design process which simultaneously engages with physical form and the materials of computation.

[20] Ullmer, B., Kim, E., Kilian, A., Gray, S. and Ishii, H., *Strata/ICC: Physical Models as Computational Interfaces,* Extended Abstracts of Conference on Human Factors in Computing Systems, (CHI 2001), Seattle, Washington, ACM Press, (2001).
[21] Ullmer, Brygg, The Tangible Media Homepage, http://tangible.media.mit.edu/projects/strata/strata.html, World Wide Web, (2001).

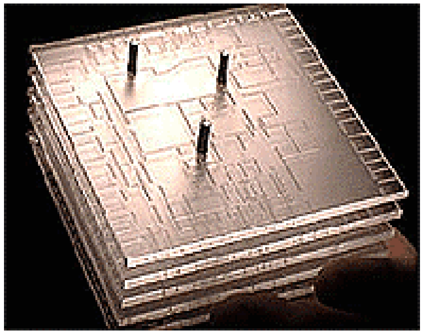

Figure 5.15 Brygg Ullmer, *Strata*, layers of plexigalss with cut grooves for circuitry, 2001.

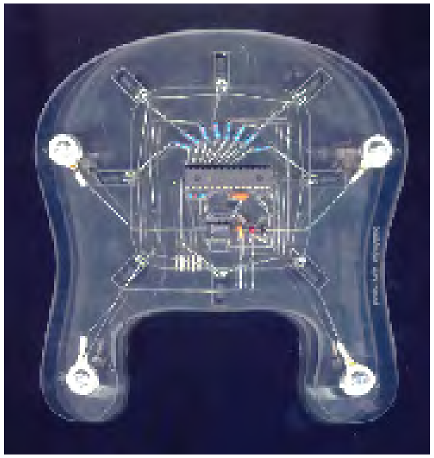

Figure 5.16 Brygg Ullmer, layer from *Strata* with integrated chips, wires and resistors.

Electronic Musical Instruments

Live musical performance has almost always involved the live, on-stage, manipulation of some *physical* object or musical instrument. People play a violin, hit drum or even just bang a stick on the floor. Digital and electronic musical instruments often aspire to recreating this kind of intimate, expressive relationship with a physical object. Consequently, they must to be incredibly sensitive, robust and ergonomic. They must be able to be touched and preferably held by the performer, if not easily moved around the stage with. And of course, they should also sound good. While this may seem like an easy task, given today's technology, it is not. Most digital and electronic musical instruments are physically, incredibly crude, when compared to their analogue counterparts. They are often fragile, bulky, and difficult to play, and build.

To become sensitive, ergonomic and expressive performance objects, electronic and/or digital instruments have utilized a few basic strategies. One strategy is simply to eliminate the need for a player to touch a physical object, as both the Theremin and its grandchild, Tod Machover's *Sensor Chair* (Joe Paradiso, Tod Machover, Ed Hammond, and Neil Gershefled), with capacitive sensing, do.[22] Physical instruments that require the touch of their player, have made themselves playable (light and ergonomic), by being either controllers (basically just sensors that are connected to off-board multimedia computers, synthesizers, samplers and speakers), or stand-alone

Figure 5.17 Tod Machover performing the Sensor Chair in a 1997 performance of the *Brain Opera.*

[22] Paradiso, J., *Electronic Music Interfaces: New Ways to Play*, IEEE Spectrum Magazine, Vol. 34, No. 12, pp. 18-30 (Dec., 1997).

objects with limited musical functionality. The ideal stand-alone instrument would have built in sensors, musical synthesis or sound generation and speakers. Barring the analogue Theremin, few electronic instruments do this. Instead, most digital or electronic instruments are controllers, with music and sound generation happening off-board.

Historically, there has been extensive work in all sorts of novel physical devices and instruments for performing live electronic or computerized music. In general, there has been trend in the design of these electronic and digital instruments to copy the form factors of the past; to make electronic keyboards, violins, and guitars. At the same time many creators of controllers have attempted to truly depart from the forms of the past and the square. In discussing her latest instruments, the *Talking Stick*, Laurie Anderson said:

> "The *Talking Stick* thing has been very satisfying. I'm on a campaign against rectangles. Let's get away from keyboards - typing and musical. It's a digital sampling machine, shaped like a harpoon." [23]

Musical Controllers

Musical controllers are a great example of the advantages and disadvantages of using a multimedia computer when working with novel physical computing objects. These computing, musical instruments

[23] Takiff, Jonathan, Laurie Anderson Interview, Philadelphia Newspapers Inc, World Wide Web, (1998).

separate the sensing or input of the instrument, from the speakers, processing, power source and synthesis engine. This allows controllers to be far smaller, lighter and more finely designed than their stand-alone counterparts. Controllers can also control a range MIDI devices and software, giving them broad musical possibilities and allowing creative people to really experiment. While this can be powerful, it can also lead to a mix and match pairing of music with a controller whose design has little to do with the musical needs or output of the instrument. Another drawback of controllers is the physical separation of the player from the speaker or acoustic source. This separation denies the player tactile feedback, and the audience spatial understanding of the music. Musical controllers that are both arbitrarily linked to musical content, and that have a physically remote sound source, can be confusing and unbelievable to the audience.

Stand-Alone Instruments

Stand-alone computing objects have all their computing functionality on-board, including processing, input sensing and output devices like screens or sensors. Because getting all the functionality of a full sized PC into a handheld object is nearly impossible, stand-alone computing objects tend to focus on taking advantage of the constraints of their materials or parts. Small objects need small prefabricated materials, and prefabricated materials usually have functional constraints related to size. For instance, small speakers are limited in their audio output. Applications for stand-alone musical instruments are specifically designed to take advantage of the limited functionality of on small board devices like processors or speakers. As a result, stand-alone objects generally have a more specific relationship between their physical design and software. They also, however, leave little room for redevelopment or reprogramming. In performance, stand-alone computing instruments have many compelling advantages. They allow the sound to emanate spatially from the player, as it does in an acoustic instrument. This can provide the player with a sense of personal and physical control similar to what they might find in a violin. They can also allow for freedom of movement and physical intimacy. Unfortunately, creating instruments with a full acoustic range can also require these instruments to be bulky, heavy and constrained by their materials.

Michael Waisvisz, *Crackle Synthesizer*

Waisvisz's *Crackle Synthesizer* is a wonderful example of a successful integration of all the parts required to make an electronic, stand-alone instrument. His instrument integrates all the classic elements of electronic instruments, like those found in classic room-sized synthesizers, into a human-scaled instrument. These elements include buttons and knobs (switches and continuous sensors), speakers, and circuitry for synthesis. But even when reduced to this human-scale, his ability as a performer to manipulate the object freely is sorely limited by its bulky array of parts. While Waisvisz's solution to these limited materials is excellent, he is still hampered in creating his instrument by the conventionality, size, weight and shape of its prefabricated parts.

Figure 5.18 Micheal Waisvisv, *Crackle Synthesizer,* 1976.

Michael Waisvisz, *The Hands*

Michael Waisvisz's *The Hands* is an excellent example of many of the positive and negative aspects of a controller. This instrument consists of two electronic keyboards strapped to his hands. By relating its design to the form and functionality of the piano, *The Hands* builds on a familiar and playable instrument. At the same time it creates a new kind of instrument by redefining its relationship with the body and the hands. The keyboards of *The Hands* are smaller than an both actual piano, or stand-alone digital instrument, could ever be. This means they can be strapped to his hands like no piano ever could. But while he has created a new relationship between the keyboard and his body, Waisvisz's *The Hands* is still severely limited by the circuit boards and sensors that are mounted on them. *The Hands* consist of two stiff boards that must be strapped onto his hand, rather than an instrument integrated into a glove on his hand, or easily held in his hand. *The Hands* is also a generic MIDI controller, so the sound and music it controls can change as easily as the synthesizer to which it is attached. It's design reflects that generic state. Finally, its speakers are off board, which can lead to a real disconnect between performer and sound.

Figure 5.19 Micheal Waisvisv, *The Hands,* 1984.

Dan Truman and Perry Cook, *BOSSA, Bowed Sensor Array*

On board speakers placed directly on this controller overcome what is often a perceptual disconnect between the sound source and the player of digital instruments. This performance instrument combines a unique spherical speaker array (Dan Truman and Perry

Cook), with five commercial pressure sensors, and a rotating sensor stick that can detect the angle and the placement of the player's hand. Putting the speakers inside the instrument makes the performance of this object far more intimate. At the same time, the weight and size of the speakers prevent it from being held in the players hands, and limit its physical relationship with the player. According to Truman himself, the sensors on the instrument break regularly and have to be replaced. The sensors are arranged in a familiar violin-like format for bowing.

Figure 5.20 Dan Truman and Perry Cook, *BOSSA, the Bowed Sensor Array,* 1998.

Curtis Bahn, *BubbaBall*

The *BubbaBall* uses a 22 inch spherical speaker array (Dan Truman and Perry Cook), combined with "five force sensitive resistors (FSR's) under squishy foam, a dual axis accelerometer for tilt and shake data, and five latching switches. The dodecahedron form for the *BubbaBall* comes from a gutted children's toy."[24] This is all connected to an off-board music system. By putting sensors right on the speakers, this ball becomes a handheld instrument. (Though given the 22 inch speaker array Bahn must be physically quite large.) Because the *Bubbaball* makes its own sound, the player gets wonderful tactile feedback from the acoustic vibrations. The ball-like form and pressure sensors make for a successful handheld instrument that the player squeezes. In this way, this is similar to my embroidered instruments. However, I think it is safe to say that this instrument is not really very squeezy. It

Figure 5.21 Curtis Bahn, *BubbaBall.* 2000.

[24] Bahn, Curtis, Homepage, http://www.music.princeton.edu/~crb/Activities/bubba%20ball.html, World Wide Web, (2001).

is a hard plastic shell that has some foam rubber over its surface where the sensors are. Moreover, there is not a correspondence between the physical design of the instrument and the music it plays.

Laurie Anderson, Interval Research and Bob Bielecki, *Talking Stick*

Laurie Anderson's *Talking Stick* is in many ways the ultimate performance controller that truly emphasizes form factor and performer mobility. This lighted six foot long, musical stick is wirelessly connected to a central MAX controlled MIDI system. It has no on-board music making capabilities. It contains a linear potentiometer, one pressure sensor and six switches. It transmits sensor data wirelessly to a remote computer and sound system.[25] The instrument was designed for Anderson's performance of Moby Dick, so its harpoon-like shape has a clear relationship to the story. Moreover, Anderson dances with it and moves freely about the stage, something she could not do if it were not light and wireless. This instrument was designed by Anderson and a research team at Interval and mechanically engineered by REM Design.[26]

Figure 5. Laurie Anderson, Interval Research and Bob Bielecki, *Talking Stick*, 1998.

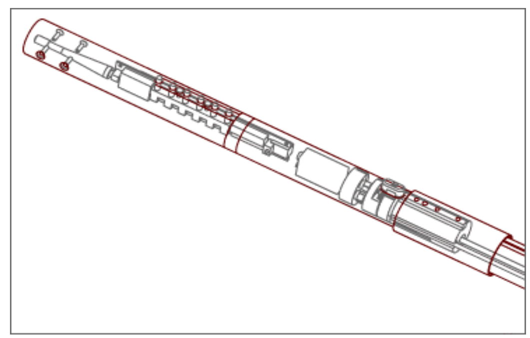

Figure 5. REM Design, CAD image of *Talking Stick.*

Conclusion

This chapter has presented a number of areas, including robotic assemblage, industrial and product

[25] This information was provided by Geoff Smith, former Interval Researcher.
[26] REM Design Homepage, http://www.remdesign.com/port4.html, World Wide Web, (2001).

design, and tangible human computer interface, in which the physical and aesthetic transformation of computing technology is taking place. It has also presented electronic musical instruments as a model for that transformation. Despite the great advances that these areas of research are making in transforming physical computing objects, there is still much room for the use of smart and active, sculptural computing materials, in both the sketching and design process, and final creation of physical computing objects. Smart computing materials that provide artists with the ability to directly sketch will enable a different type of design process where the *actual* aesthetic possibilities of the materials play a role in the final proposal. Computing materials that are shapeable and that possess unusual tactile properties will also allow designers fuller range of symbolic expression. Finally, smart and shapeable computing materials will allow designers to directly investigate the relationship of physical form and computation.