Chapter 6.

Future, Smart and Sculptural Computing Materials

For computers to truly become sculpturally, materially, and symbolically transformed, and play new roles in peoples' lives, the generic palette of computing materials that designers and artists work with must expand and change. No longer will plastic, buttons and little screens suffice. New computational materials must emphasize *design* properties that are human-scaled, or capable of being sensed by people. Currently, most emphasis on developing new materials for computing technology occurs at a microscopic scale. Engineers work to make ever faster and smaller transistors and chips. But smaller technological materials do not necessarily solve the problems many designers are facing. New computing materials must provide artists and designers with more plastic control and immediacy, allowing artists to experiment and iterate. They must also provide artists and designers with visual, tactile and mechanical variety. Finally, they must enable artists and designers to truly explore the relationship between physical form and

Design Properties of Sculptural and Active Computing Materials

Enable the simultaneous investigation of physical form and computation. New sculptural and active computing materials must allow artists to simultaneously investigate physical form and computation. To do this, these materials must function simultaneously as physical design materials and active computing materials

Provide tactile, visual and mechanical variety. New sculptural and active computing materials must offer designers and the people who experience computers a variety of tactile, visual and sensual experiences. Industrial designers have always chosen their materials to communicate something about the object. Fabric is soft, warm and intimate. Metal is colder and more formal. Wood can be warmer. Most physical computing objects demand an input device that usually responds to touch. Yet people have almost NO sensual incentive to touch their computers, and designers have almost no choice in what the people who use computers touch. New physical computing materials must possess a variety tactile qualities, visual qualities (including transparency and opacity), and a variety of colors. Finally, they must provide artists and designers with a variety of mechanical properties to choose from, such as stiffness, elasticity, strength, and softness.

Be directly shapeable or sculptable. New sculptural and active computing materials must be shapeable so that designers and artists can create objects that physically reflect their artistic vision. They must provide designers and artists with immediacy so they can experiment and iterate with the physical properties of computational objects as quickly and easily as they can with software.

computation through direct manipulation. To do all this, these design materials of computing objects must be more than inactive, hard, plastic shells or housings; they must be computationally active.

The ideal sculptural and active computing material might be a sort of computer clay which designers or artists could use to form monitors, speakers and even processors into any *shape*. But there remains a lot of work to do before we have this magical computational clay. In the meantime, scaled back, smart or multi-functional computing materials can help us begin to physically transform computing, as well as to explore the relationship between physical form and computation.

The projects presented in this thesis use two strategies to suggest the possibilities of future sculptural and active computing materials. The first is strategy is to use smart or multi-functional materials**.** Smart materials take on multiple functions, reducing the number of separate *prefabricated* materials necessary to create a computing object. The second strategy is networked computing materials. These are ultimately *raw* materials that are formed from many networked *prefabricated* computing devices. Like the bonds between atoms, network connections can let many prefabricated devices become a raw material.

Smart, or Multi-Functional Computing Materials

Phillip Ball, in *Made to Measure*[1] describes smart materials in the following ways:

> "Smart materials can be thought of as materials that replace machines..."
>
> "Smart materials have the potential to simplify engineering considerably. Moving parts have a tendency to break down, whereas smart devices in which the *materials* themselves do the job of levers, gears and even electronic circuitry, will contain less potential for malfunction.
>
> "smart material systems… are materials that are hooked up directly to microprocessors."

The essence of what Ball is saying here is that smart materials *integrate* the functionality of various separate parts into a single material. This is mechanically efficient because it eliminates the need for parts to be physically connected or to interact. It is artistically efficient for the same reason. Making any object from a single material is almost always simpler than integrating multiple materials. As long as a piece of furniture is all wood, you can cut and glue it together relatively easily, and as long a piece of furniture is made of all metal you can cut and weld it easily. But making a piece of furniture from both metal and wood is far more complex. Mechanical fasteners between the two must be used. The properties of the wood (for example how much it expands with temperature and how soft it is) and their interaction with the properties of the metal must also be taken into

[1] Ball, Phillip, Made to Measure: New Materials for the 21st Century, Princeton, University of Princeton Press, (1997) pp.103-110.

account. Add more materials to this hypothetical piece of furniture, and it becomes even more complex. IF one can integrate the role of these multiple materials into one material, the designer will have a far simpler, and more direct building and manufacturing process.

The Materials of an Acoustic Violin

The materials of an acoustic violin provide an excellent model for the potential of smart or multi-functional, computing materials. An acoustic violin is an interactive object of incredible precision, ergonomic design and beautiful musical output. Like a computational object, an acoustic violin has an input device (strings), an output device (an acoustic cavity that makes music), and a means to transform the input (the form and properties of the instrument), into the output, music. The major material of an acoustic violin is wood. It performs many functions. (While there are additional materials, like string, horse-hair and steel, what I am getting at here is the *multi-functional* nature of wood in the violin.)

Wood is the waveguide, or the means of transporting the input signal, (the vibrations from the strings), to the output device, (the resonant cavity). It is also the output device; it amplifies and creates sound waves. It transforms the input signal into music, by controlling the frequency and timbre of the music output with the shape and size of the cavity. It is also the manor mechanical substrate and design material of the instrument. It holds all the parts together, and is shped to fit easily into the players hands.

Figure 6.1 A violin is made mostly from the smart material of wood.

The wood of the acoustic violin is also truly sculptural. It can be shaped, cut, bent, drilled and glued quite precisely. The process of shaping the wood of a violin allows its designer to control both the ergonomics and musical output of the violin, because both the shape of the violin, and the material properties of the wood, have a direct relationship to its musical output. A violins size is related to its frequency range (for example cellos make deeper sounds). The shape of the arch of the back of the violin can be used to create subtly different vibrations. The shape of the sound holes also directly affects the sound of the violin. And the wood itself creates a very different timbre than metal would. In fact, different types of wood are used for different parts of the violin to create different vibrations.[2] In this way, we can understand the violin as an interactive object whose physical form and materials is directly related to its sound output, or *computational function*.

The Materials of its Physical, Computing Counterpart

So what would it take to create a physical, computing version of this instrument? Assuming one could actually create a computing instrument that was as responsive and sounded as good as an analogue violin, building it would require *MANY computing materials*. A physical, computing violin would need:

- **Sensors** to translate the mechanical energy of playing into electricity that communicates with a CPU.

[2] Johannsson, Hans, Violin Making, http://www.centrum.is/hansi/, Iceland, World Wide Web, (2001).

- **Wires** to send electricity to a chip.
- **A computer chip** on a circuit board processes the information from the sensors and creates an audio signal.
- **More wires** to send that signal to a speaker driver.
- **A speaker driver** to translate the signal back to the mechanical vibrations of sound.
- **A resonant cavity** to amplify the sound, (this may or may not be made from the substrate material.)
- **A mechanical substrate material** to hold it all together.
- **A power supply** (a battery or wire) to power it all.

Almost every one of these materials is a *prefabricated* material, and cannot be reshaped for either ergonomic or musical reasons. Moreover, an instrument created from these materials will be neither light, nor easy to play. The physical requirements of creating a mechanically stable object that can translate mechanical energy from the sensors, to electrical energy for the processors, and back to mechanical energy at the speaker, guarantee, that the digital and physical violin would need obtrusive wiring throughout, and a sturdy and inevitably bulky way to support it all.

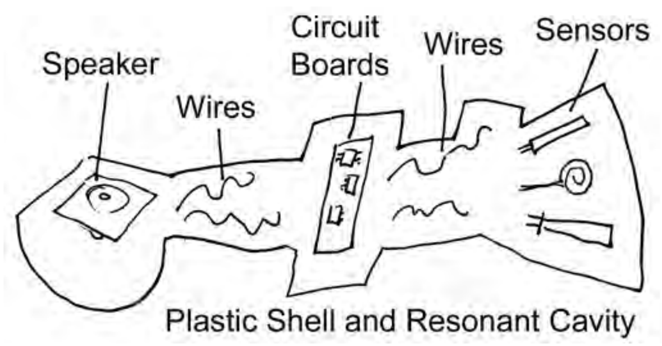

Figure 6.2 Diagram of the materials necessary to create its digital/physical counterpart.

When compared with its computing counterpart, the materials of an acoustic violin are unbelievably concise. In fact, if the acoustic violin had come *after* the computing version, we would think of the wood in the violin as the ultimate *smart* material. The wood of the acoustic violin replaces the speaker, amplifier, CPU, wires and housing material of the digital version. The wood is smart or multi-functional material, performing many acoustic and mechanical functions simultaneously.

Ideally, smart or multi-functional materials would perform as many functions as the wood of the violin. While creating a computing material that can perform as many functions as the wood in a violin is still far off, a single material, that can perform even a few computing functions simultaneously, can make a big difference in both the design process and its results. A scaled-down approach to creating smart computing materials might integrate least two of the following functions: sensing, mechanical substrate, electrical transport, visual output, audio output, and computing. And like the wood of the violin, smart computing materials should be wonderfully sculptable, able to be molded, sized, joined or bent to the shape appropriate for the object they forming.

A silicon chip is, itself, a highly integrated or smart material, which might serve as a model for a smart, sculptural, computing material. Silicon chips replaced complex logic circuits that had been made from many transistors and electronic components parts. Silicon is a remarkable material because it can be transformed into conductor, insulator or semiconductor. A smart sculptural computing material might also be transformable into different functions, like speaker, monitor or CPU.

Small is *Not* Enough

The need to mechanically simplify computing objects by integrating the functionality of many different parts into a single material is why simply making silicon chips SMALL is not enough. Today's computational objects are a system of mechanically attached, *human-scaled* materials, and microscopic silicon chips are just a part of

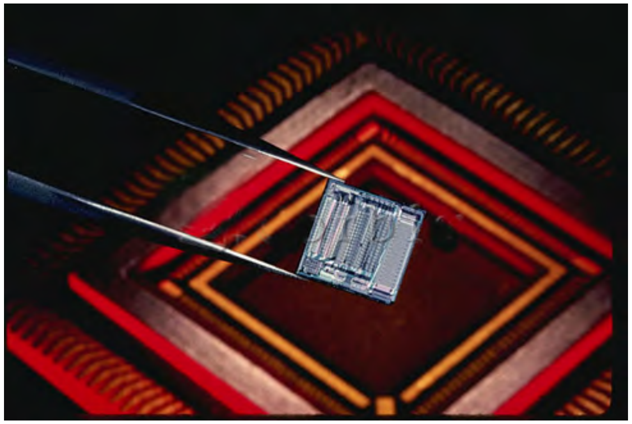

Figure 6.3 Miniature microchip compared to giant housing and pins around it

that system. These tiny chips are themselves only the core of a larger and more rigid package, which is designed to preserve their electrical properties, and allow them to communicate with other parts of the object. To send and receive electrical signals to other components, the electrical leads of these tiny chips must scale up; their microscopic pins must "break out" to reach large pins, which in turn reach the wires and connectors, on larger sensors and output devices. All these wires and connectors must then be held on a rigid surface, or inside a plastic box so that the electrical connections do not break.

Networked Computing Materials

It is possible to understand a network of many *prefabricated* computing devices or elements as an *raw,* networked material. While raw materials are capable of being divided into smaller chunks that still retain their material properties, they are ultimately composed of many individual elements (atoms or molecules), which, like precursor elements, cannot be broken down. It is the connections between these molecules or atoms that give a *raw material* its sculptablity or shapeability. In this way, a mass of *prefabricated computing elements* can become a material, by virtue of its network connections. It is possible to imagine schools of networked robots functioning as this sort of material. Wireless networking between separate computing elements in a single computing object, can also help reduce bulky wiring materials, and make materials more shapeable and practical.

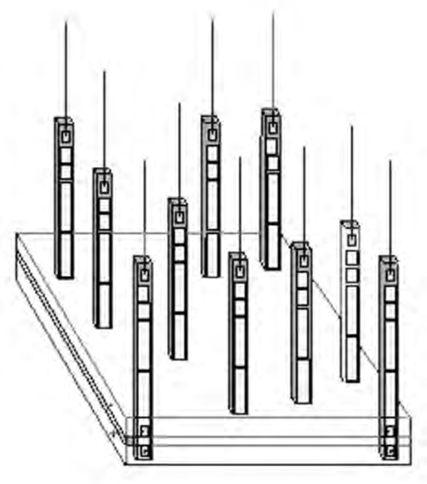

Figure 6.4 Sussman's *Pinless Processor,* 1999.

***Amorphous Computing*, Jay Sussman**

Jay Sussman's *Amorphous Computing*[3] and his *Pinless Processor* represent a far-reaching vision of networked computing materials. Sussman has proposed many ways to create a material made of thousands of wirelessly connected tiny pinless processors that can compute. While his work has focused primarily on software for these interconnected processors, it has also explored some possible hardware solutions. These solutions include creating a substrate of layered power and ground to plug the *Pinless Processors* into. Wireless connections between the processors would provide communication. But *none* of these hardware solutions creates materials that are actually physically and mechanically paintable, amorphous, or skin-like. That is because, while Sussman's focus has not been on the mechanical properties suggested by the name of his research, but on the software model. Thus, when he claims that the hardware problem is trivial,[4] it is based on the fact that truly achieving the physical and mechanical material properties that he uses to describe his research, is not really his goal. But if this research were to emphasize enabling the physical and mechanical properties of paintable computing, it would find a wealth of additional applications. Creating computing materials that are *truly* physically, paintable and amorphous will have tremendous ramifications and use for artists and designers working in computation.

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[3] H. Abelson, D. Allen, D.l Coore, C. Hanson, G. Homsy, T. F. Knight, Jr., R. Nagpal, E. Rauch, J. Sussman, R. Weiss, *Amorphous Computing*, Communications of the ACM, 43, 5, (2000).

[4] Ibid.

The Potential of Structured Computing Materials

There is tremendous potential for the development of structured or composite computing materials. I imagine these materials as a sort of computing wood, or more advanced computing textiles. Like silicon, these materials might have the potential to be transformed through different processes into various electronic components or precursor elements, like screens or displays. These materials might come in sheets that could be cut, bent and sewn or glued together. The sewing and gluing would both electrically and mechanically fasten them together. The materials might then be “treated” or coated to turn part of them into a display of sensor or a speaker. This could allow for a much more direct building and design process.

How My Portfolio of Projects Fits In

The projects presented in this thesis only begin to suggest the possibilities of sculptural and active computing materials. This thesis develops electrically active textiles as smart or multi-functional, and active, sculptural, computing materials. These smart textiles function as the physical housing or design material, power distribution materials, wires, sensors, antennas and - in the case of the *Firefly Dress* - a display substrate. Design projects in this thesis that use smart textiles include: the *Firefly Dress and Necklace*, the *Ball Gown*, *Serial Suit, Piecework Fabric Keypad, Musical Jacket, Electronic Tablecloths,* and *Embroidered Musical*

Instruments. This thesis presents the *Triangles* as an example of networked sculptural computing materials.

While some of the projects presented in this thesis are stand-alone, many rely on off-board computing and speakers to keep the computing objects as light and textile-like as possible. In this way, objects like the embroidered musical balls are *smart material systems* [5] that consist of smart fabric balls connected to an external PC and speakers. As a smart material system, these materials take advantage of off-board computers, to do much of the computation and media output. However, by replacing quite a few separate parts of computing objects, these smart textile objects demonstrate the artistic impact that more fully developed smart and active computing materials will make when they actually arrive.

[5] Ball, Phillip, Made to Measure: New Materials for the 21st Century, Princeton, University of Princeton Press, (1997) pp.103-110.