Chapter 1.

Introduction

Have you ever wondered why computers aren't pretty? Why they are hard? Why they are square? Why they don't feel good? Or why wearable computers are still unfashionable and unwearable? Is this a reflection of the aesthetics and priorities of the male dominated engineering world that creates them? Or are there more fundamental technological limitations that prevent people from having aesthetically[1] fulfilling, if not downright desirable computers and computing objects? And if artists and designers could take computing technology even further, physically transforming it into soft, furry and sensuous, tactile objects, would that material transformation also expand and change the role and meaning of computing technology in peoples' lives? This thesis asserts that there are fundamental technological limitations that prevent physical computing technology from becoming not only tritely

[1] By aesthetics, I am primarily referring to what the Oxford English Dictionary On-line, World Wide Web, (2001) defines as: "Of or pertaining to sensuous perception, received by the senses." At the same time I am loosely referring to its other definition aesthetics, "Of or pertaining to the appreciation or criticism of the beautiful."

pretty, but also from developing a sophisticated, sensual and visual, artistic language. These same limitations also prevent artists and designers from radically changing peoples' aesthetic, or gut response, to computing technology, and therefore its meaning and purpose in their daily lives.

In response to this problem, this thesis presents a portfolio of aesthetically transformed, expressive computing objects, the new technologies that enable that transformation, and the artistic and design theories that direct and describe this work. These contributions include electronic fashions, squishy, stuffed, embroidered musical instruments, new physical interfaces, and the new, smart textiles and processes, including fabric pressure sensors, keypads, circuits and connectors, that make these aesthetically unusual computing objects possible. Together, these artistic and technical contributions act as a proposal for a future, three-dimensional design/technology practice that seeks to transform computing technology, both aesthetically and technically, through smart and active, sculptural computing materials. And while the results of this thesis are multidisciplinary, integrating artistic theories, processes and artifacts with electronics, software, materials science, and manufacturing, the main contributions of this thesis are the portfolio of expressive computing objects and the design/technology proposal that these objects present. This proposal for a future design/technology practice combines hands-on design and artistic practices founded in the decorative and industrial arts, computing technology, and novel, physical, smart sculptural materials in attempt to truly change the physical form and sensual properties of computing technology. My hope is that together, the technical, artistic, and theoretical results of thesis will ultimately point the way to a sophisticated, sensual and visual artistic language for physical and material computing technology; a language which will ultimately enable the power of computing technology to find a more expressive, sensual and creative role in peoples' lives.

Expanding on the Problem

Five years ago I came to the Media Lab to find myself surrounded by dreary beige boxes. I was a sculptor, artist, and designer of physical objects who was suddenly confronted with a world of neutral PCs. All around me people simply ignored the material presence of computers. Computers were literally *physically* invisible. People seemed to be aware of only the *virtual* space inside the computer's monitor. But a revolution was about to take place. Researchers in Things-that-Think[2] were taking computation out of its box, and into the world around us. No longer were computers bound to the desktop and invisible, suddenly they were "ubiquitous"[3]. Unfortunately, they were also ugly and physically ill suited to their tasks. I

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[2] Things-that-Think is a research consortium that was begun in 1996 at the MIT Media Lab. According the MIT Media Lab website, World Wide Web, (2001): "This consortium explores ways of moving computation beyond conventional sites, such as PCs or laptops, and adding intelligence to objects that are first and foremost something else."

[3] Weiser, M., *The Computer for the 21st Century*, Scientific American, (1991) pp 94-104.

was constantly confronted with computing objects that were rampant with physical paradoxes. Early wearable computers were *heavy, sharp, metal boxes*. Researchers also seemed to think that by simply sticking a piece of technology onto an object, the two would miraculously become integrated. Bulky commercial sensors were pasted onto sculptural musical instruments. Monitors were inserted into walls and onto doors to create smart rooms. Chips were stuck into coffee cups. I began to wonder if the makers of these new computing objects saw the physical aesthetics of their research as superfluous or were simply completely, visually unaware.

As an artist, I deeply felt that the act of creating a physical computing object *had* to be at some level about visual design, material processes and aesthetics. During my early work creating physical interfaces for the electronic musical instruments in Tod Machover's *Brain Opera*, I realized that the ugly computing objects around me were not simply the result of a lack of aesthetics and design training on the part of their makers. These objects were also the result of the poor and limiting physical computing materials with which they worked. Displays, chips, buttons, sensors, circuit boards and wires were not a particularly rich, broad or sculptural palette of physical materials. Moreover, when these materials were taken out of their plastic boxes, they became physically fragile and awkward. I began to believe that the only way I could physically and sensually transform computing objects was with new, physical computing materials. I also began to believe that the engineering goals of creating faster and smaller parts would not solve the artistic and design problems I was facing. I had to create computing materials that would meet my aesthetic and practical goals as a designer. These materials had to be varied and rich in their mechanical properties and truly sculptural. They also had to integrate computing technology directly into the sculptural, design materials I wanted to work with, materials like textiles.

The creation of new, smart materials that allowed computing technology to exist comfortably in non-traditional physical contexts, like clothing and jewelry, *did* help overcome both the practical problem of integrating technology into everyday objects, and the formal boundary to aesthetic development. However, these were not my only artistic goals. Ultimately, I wanted people to feel differently about computing technology, to feel empowered over it, to question it, and to turn it toward creative and expressive ends. Industrial design and product design have demonstrated clearly that the physical form and material properties of an object can communicate its purpose and *function* to people. From my training in the fine and conceptual arts, I had learned that an object's materials could contribute to and transform its meaning *symbolically*. I believe that one important and unexplored way to change peoples' attitudes toward and use of computing technology is to transform its physical form and material properties *aesthetically*. By making technology physically and materially humorous, intimate and even strange, I ultimately hope to give it a more creative and expressive role in people's lives. By making technology from familiar and intimate materials like textiles, and with an everyday, down-to-earth process like sewing, I also hoped to give people a more empowered feeling over technology.

Expanding the Contributions

The total contributions from this thesis include a proposal for a future three-dimensional design/ technology practice, a portfolio of sensually transformed, expressive computational objects, and the smart and active, sculptural computing materials, in this case smart textiles, that enables that transformation.

A Future Three-Dimensional Design/Technology Practice

When today's artists and designers work with the physical materials of computers they usually work in a CAD-based process that is sculpturally remote. In fact, many designers of consumer electronics never even touch the *real* physical materials of computers, whether plastic or electronic, but instead work in models and through scenarios. And while visionary work in tangible computing[4] by researchers like Hiroshii Ishii and Durrell Bishop has attacked both the inactive housing materials and some of the electronic guts of computers, there is still little work that integrates the design (housing) materials with electronic or active computing materials. There is also little work in which

[4] 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).

designers sketch directly in electrically or computationally, active physical computing materials, or use them for a direct aesthetic and artistic exploration of physical form and computation. Moreover, there is almost no plastic shaping of active computing materials. Instead, most designers looking to materially transform or shape computing technology use unusual materials like wood and paper to cover existing chips and circuits, and additive methods to assemble a variety of prefabricated, rigid and square parts. But imagine being able to cut a piece of sensor/speaker plaid, sew it together, and create a musical instrument, a new computer mouse, or a soft computerized doll. Imagine picking up a piece of clay and shaping it into an object that interacts with software, and creates images related to its shape and size. Imagine directly and materially shaping a computing object, and immediately seeing the effect of that sculptural process on music, a story or an image.

In the tradition of the Media Lab, the future design/ technology practice proposed in thesis lies at the crux of technology and culture, demonstrating how technology can change art and design, and how the needs of art and design can transform and drive technology. This proposal presents a material and process-oriented approach to technology design that integrates experimental technology research, the Media Lab's tradition of project-based research, and a hands-on design tradition that emerges from the industrial and decorative arts. This proposal asserts that without an aggressive and intimate, hands-on approach to the physical materials of computing technology, it is not possible to master, control or understand their design, aesthetic and expressive properties. This proposal also insists that designers and artists create and invent new, sculptural and active, computing materials that meet their creative and aesthetic needs. Through both the direct creation and manipulation of the physical materials of computers, this new technology/design practice hopes to create computing objects that are both aesthetically and technically innovative.

The following tenets are presented as a guide for this future three-dimensional design/technology practice. While I believe these tenets have broad ramifications for any design practice dealing with physical computing or electronic technology, this summary is not meant as a prescription. Instead, it is meant as unique approach that can help designers of physical computing objects reach their practical and creative goals.

***Deeply* transform physical computing technology; sculpturally, materially and aesthetically.**

- Do not accept prefabricated computing materials or allow them to determine the shape, form, sensual or tactile properties of your work.
- Create your own smart and active, sculptural physical computing materials. Make these materials meet your design and artistic needs, or turn your preferred design materials into active computing materials. Make your physical computing materials sculpturally and artistically manipulable in a direct, hands-on manner. Integrate as much computing functionality as possible into a single material.

- Understand the mechanical, electrical, sculptural and symbolic properties of your computing/design materials.

Explore the relationship of physical shape and computation formally.
- Create computational objects that are not physically neutral (like a mouse), but whose shape and material properties have meaning and relevance in software.
- Create cognitively clear and technically stable design control objects for initial formal exploration.
- Mix and match physical objects and software and to see what happens. Iterate between physical form and software.

Create new computing objects, don't just stick microchips in existing objects.

My Artistic and Aesthetic Vision

My personal artistic and aesthetic proposal is not about making computing technology pretty or tasteful. The ability to make computing technology pretty or even beautiful is only one incarnation of an artist's or designer's ability to truly change the meaning and physical properties of computing technology through novel computing materials. Moreover, my aesthetic is not about hating plastic. When I worked in a bronze foundry I wanted to make things that were materially opposed to bronze, things that were plastic. Now, I want to materially and sensually *invert* computing technology *away* from the hard and plastic. The motivations for this are simultaneously positive and perverse. Such an inversion is meant to make the computing objects in this thesis sometimes strange and sometimes intimate. I hope that these transformations will make people see and feel differently about computing technology, make them question its use and turn it toward more expressive and creative ends.

As my personal artistic proposal, I do not believe that the following approach is necessarily applicable to other design or artistic practices. It is my own, a refection of my training, goals and beliefs as a creative person.

> **Aesthetically *invert* the symbolic meaning of computational objects through antithetical and unexpected forms and materials.**
> Computing objects are hard, plastic, formal, square, heavy, smooth, remote and beige. Make them soft, fuzzy, desirable, sensual, round, light, squishy, elastic and colorful. Computing objects are square and industrial. Make them rounded and organic. Make computational objects more approachable and accessible through design and materials, not more elite or isolated. Make computational objects materially surprising and humorous.

The Portfolio of Expressive Computing Objects

Examined from the tradition of the visual arts and design, the portfolio of objects presented in this thesis can be understood as lying somewhere between the practices of industrial design, the decorative arts, technology design, and physical interface design. The objects presented in this thesis are simultaneously musical instruments, physical computer interfaces, fashions and other "everyday" objects that have been transformed through computation and smart materials.

The objects in this thesis are also “everyday” computing objects and physical interfaces that have been aesthetically transformed through unusual sculptural computing materials and an intimate craft/ design process that finds its roots in the industrial and the decorative arts. These objects range from single hand-made objects, like the *Firefly Dress and Necklace*, to mass-produced objects like the *Triangles* and *Musical Jackets*. Together, they form a horizontal exploration of the expressive relationship of physical form, computation, the physical materials of computation, ornament, and three-dimensional design.

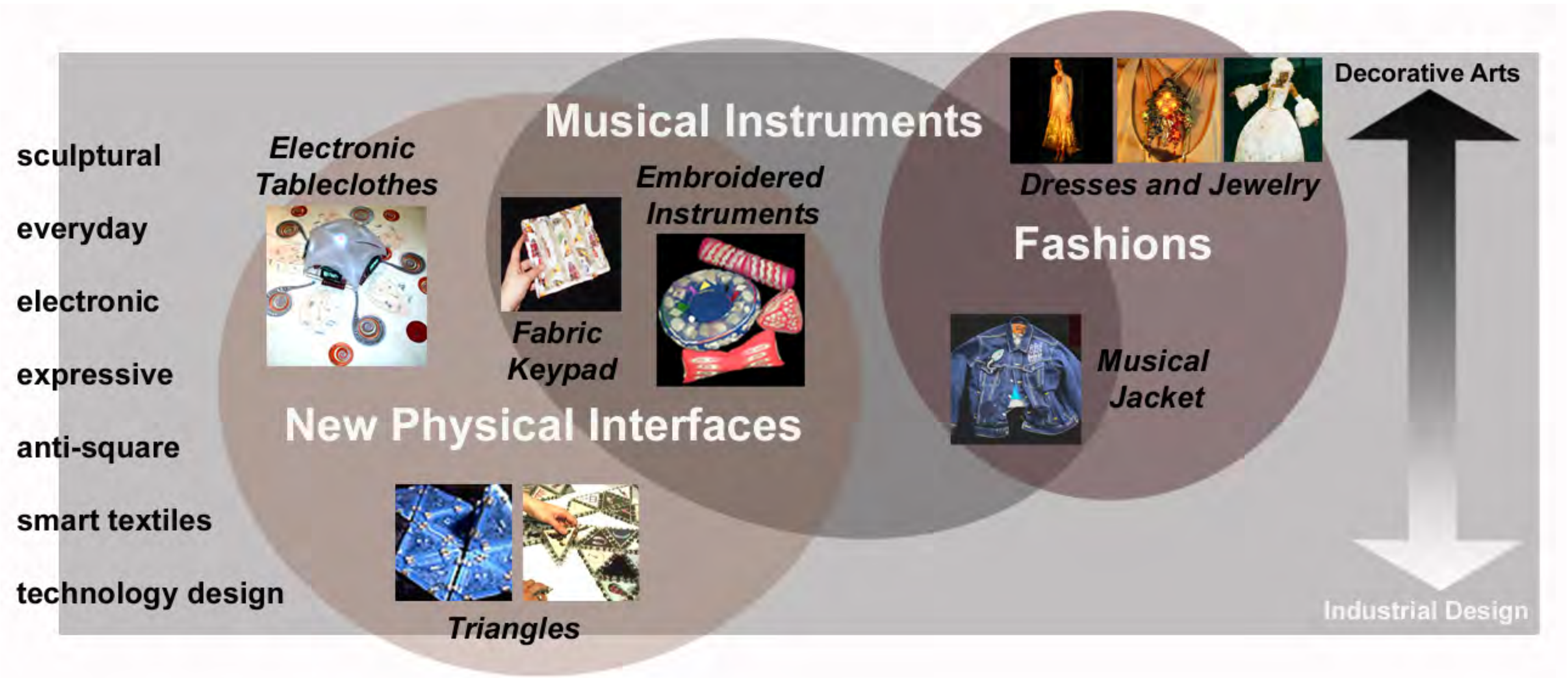

Figure 1.1 The Tree of Projects.

As both aesthetic objects and technology research, the computing objects presented in this thesis make the proposal for a future three-dimensional design/ technology practice. But while these objects can be understood as *a proposal* for the future, it is essential to this proposal, that these objects and enabling technology are not merely theoretical. They are not unrealized design proposals that exist only on paper, and are unaware of the processes and materials necessary to create them. Nor are they merely scenarios, stories of how imaginary technology might change our lives. Instead, they are very real, working, expressive computational objects, their applications, and the working and innovative technology necessary to create them. Ranging from electronic fashions to musical toys, these everyday objects clearly demonstrate how new and unusual computing materials, like smart textiles, can allow computing technology to be transformed from plastic consumer electronic devices into aesthetic objects that are part of the rich material world around us. In fact, it is the very reality and functionality of the technology in these computing objects that makes the proposal for a hands-on approach to three-dimensional technology design involving the direct manipulation and invention of sculptural, physical computing materials.

Contributions from the design portfolio include:

The *Triangles* and its applications
A patented digital/physical construction kit.
- Version 1, with Matt Gorbet
- Version 2, with Matt Gorbet

• *Galapagos*, a web-based story application with Matt Gorbet
• *Cinderella 2000,* an audio comic book
• *The Digital Veil*, an artistic ausdioscape with Matt Gorbet and Mary Beth Back.
• *Toy Search*, an interactive web-based game

Electronic Fashions with Emily Cooper and design students
Fashions that use electrically active textiles as sensors, circuitry and design materials.
• *Firefly Dress and Necklace*
• *New Year Eve Ball Gown*
• *Serial Suit*

The *Musical Jacket* with R. Post, J. Strickon, J. Smith, and E. Cooper
A stand-alone, wearable musical instrument that contains a patented embroidered keypad, fabric communication bus, speakers, batteries and a miniature MIDI synthesizer in the form of a pin.

Electronic Tablecloths with A. Lippman, R. Post, P. Mukerji, P. Russo
An interactive cocktail-party jeopardy game, that contains an embroidered capacitive tag reader and keypad.

Early *Embroidered Musical Instruments*, with Peter Russo
Musical instruments with embroidered pressure sensors.
• *Squiggle Ball 1*
• *Squiggle Ball 2*
• *Diamond Ball 3*
• *Circle Ball 4*
• *Circle Ball 5*
• *Ball 6, The Generic Musical Ball*

Shaped Embroidered Instruments

Musical instruments with embroidered pressure sensors for Tod Machover's Toy Symphony.

- *Sound Sculpture Pyramid*
- *Melody Tube*
- *Melody Butterfly*
- *Big Ring*

Smart Textiles: Materials and Processes

The supporting technical contributions made by this thesis are essential to the achievement of my artistic and design goals. Without these smart textiles, fabric sensing devices, and sewing processes I could not have created the expressive, computing objects shown here. My motivation for working with textiles was multiple. On the one hand, I wanted to create flexible, and durable sensors for new digital musical instruments. As interest in wearable computers emerged at the lab, I also found that I was far more interested in making clothing compute than strapping a PC to my body. Using textiles as a computing material was a solution to both. Textiles are also a wonderfully, sculptural material. They are cuttable, bendable, shapeable and easy to make quick prototypes with. Finally, they are *feminine*. Traditionally, textiles have been considered women's work. I enjoyed using them to create computing technology, something that is normally considered within the realm of the male. In addition, they are soft and squeezy.

To truly make the proposal for sensually transformed computers, I needed to keep the computing objects created for this thesis as lightweight and soft as possible. Textiles were chosen because they are soft and squeezy. Ideally, smart textiles would create soft computing objects by replacing all the hard, square materials of the computer, including monitors, sensors, chips, housings, and power supplies. The active, smart textiles presented in this thesis do not do this. They integrate housing materials, input sensors and wires, and are then used as part of a *smart material system*[5] that is connected to a central processor or PC. The chips, speakers, power supplies and displays necessary for these objects are either located off board, or cleverly disguised. Integrating all these computing materials into a single textile is the next step towards creating truly “squishy” computers.

Because squeeziness, touchability, wearability and softness are central to my artistic vision, creating smart textiles with these properties was also one of my central technical goals. Consequently, I have tried to create smart textiles that are as flexible, durable and soft as most fashion-oriented textiles. Focusing on fibers and yarns that can work with the standard textile manufacturing processes and machinery, rather than developing new machinery, helped guarantee this. There are many industrial textiles that contain unusual fibers, like glass, that are not soft, flexible or appropriate for touch. These textiles are usually made with special machines that take into account their unusual mechanical properties. Using standard sewing machines guaranteed that the yarns I worked with had mechanical properties very similar to standard fashion-oriented yarns.

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[5] Ball, Phillip, Made to Measure: New Materials for the 21st Century, Princeton, University of Princeton Press, (1997) pp.107.

The conductive yarns and woven textiles used in this thesis are for the most part pre-existing, conductive threads and woven textiles that have been re-purposed to create sewn or embroidered electronic circuitry and devices. The *Firefly Dress and Necklace*, the row and column keyboard, and the fabric data and audio bus in the *Musical Jacket* all use a very old, decorative fabric known as metallic silk organza. The machine embroidered sensors and electrodes made for this thesis are sewn from a variety of composite stainless steel threads that are usually used for static or EMF sheilding, or as mechanical composite reinforcements in products such as tires. The new materials developed for this thesis were developed at a composite level, and involve the braiding, weaving or sewing of existing yarns and textiles together.

The supporting technical contributions of this thesis include:

The first fabric keypad, a piecework row and column switch matrix.

A new electrically active, composite yarn capable of tying and electrical and mechanical knot.

An advanced process for machine sewing highly conductive and visually diverse embroidered electrodes.

An empirical model of complex impedance sensing in a smart materials system of smart textiles and central circuitry.

A definition of, and test for, the sewability and flexibility of yarns and threads.

Conclusion:

All of the projects and the supporting technology presented in this thesis are the result of my overall artistic motivation to materially and physically transform computers, and to explore the expressive relationship between physical form and computation. At the same time, they are the result of my own artistic ideas and beliefs that I have developed for years, and of the research agenda and environment here at the Media Lab. All of these factors have combined to motivate the work in this thesis. The next chapter looks at how these factors combine to form the unique body of work presented in this thesis, and attempts to further describe the motivations and ideas behind this work.