Computation and Technology as Expressive Elements of Fashion

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B.S. Art and Design
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Submitted to the Program in Media Arts and Sciences,
School of Architecture and Planning,
in partial fulfillment of the requirements for the degree of
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Abstract

This thesis explores technology and computation as elements of fashion. Far beyond the definition of clothing as a necessary protective covering, fashion exists as a way for people to express themselves to others, to reflect portions of their personality in their outward appearance, and to distinguish themselves as individuals. How can technology enhance these expressive aspects of what we wear? The goal of my research is to create examples of new types of clothing based on computation, which provide modes of expression unachievable with traditional garment techniques. In this thesis, I define an area of design and research which is a synthesis of technology, computation, and fashion. I explore the constituent properties (axes) of the design space through research experiments, and present basic software and hardware architectures on which to build relevant examples of computational fashion.

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The following people served as readers for this thesis.

Thesis Reader
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Introduction

Motivation

Every day we make conscious decisions about what we look like through our clothing. Fashion exists as a means of creating an outward appearance that reflects something about the individual, whether it is identification with a cultural movement such as punk rock, economic status as a wealthy businessman, or a personal weakness for the color magenta. The things we wear relate our bodies and our personalities to the things around us, and are extremely personal systems of identity that we construct with deliberation and care.

The development or assimilation of new technologies is a critical part of any industry, and the field of fashion is no different. The development of new materials and fibers provides fabric with a vast range of drape, texture, color, durability, weight and performance. Intricate and sophisticated machinery affords faster garment construction and embellishment. Computer-aided drafting is an established technique, and software exists for automatically drafting patterns from any set of body measurements.

But the fashion world has been slow to embrace computation and electronic technology as aesthetic elements in clothing itself. Perhaps due to a lack of knowledge about new technologies, or the absence of motivation to augment an already-abundant repertoire of resources for creation, the use of electronics has generally been limited to tools for the construction of garments, practical applications in the wearable-computing ("Wearables") realm, or novelty clothing. Only very recently have more expressive uses of electronic technology begun to surface, in small accessories (typically watches) that utilize simple rules of reactivity to control a display computationally.

Electronic technology has added a wealth of new visual stimuli to our environment. Flexible liquid-crystal displays allow the display of anything from text to colored dynamic imagery. Electroluminescent panels emit uniform washes of colored light, are thin and flexible, and can be cut into intricate shapes. Motors and resilient wires can create kinetic physical form. Computation on either desktop machines or embedded microcontrollers allows complex control of these visual elements, negotiates interactivity and reactivity through sensors or other streams of data, and provides memory and processing power. Given such powerful media, we have the ability to transform clothing.

This thesis attempts to expand the field of fashion through an informed use of computation, and to demonstrate that a synthesis of fashion and technology can be beautiful and provocative. What modes of expression can be realized through technology? How does computation on the body affect the way we think of ourselves related to society, to those around us, to those far away from us? How can computational clothing address the concepts of constructed image, personal environment, and social communication? What are wearable, beautiful things we can make with electronics? These are the questions I address through my research.

Overview

This thesis provides a brief historical survey of fashion in its role as protection, expression, and communication, with an emphasis on the technological and architectural aspects of the field. A new design space, synthesized from technology, computation and fashion, is outlined and its characteristic axes defined. Several research experiments exploring issues relating to the body, expression, and communication are presented and situated within the context of the new space.

More specifically, the accomplishments of this thesis are:

- an analysis of the history of clothing and its expressive, architectural, and practical functions
- the enumeration of specific design parameters and principles inherent to the field of computational fashion
- a set of design experiments, each exploring concepts of the body and its relationships
- the development and investigation of technical systems and techniques with which to build computational garments
- an evaluation of the research work and contextualization based on denoted axes/principles

Background: Technology in and of Fashion

The Invention of Clothing

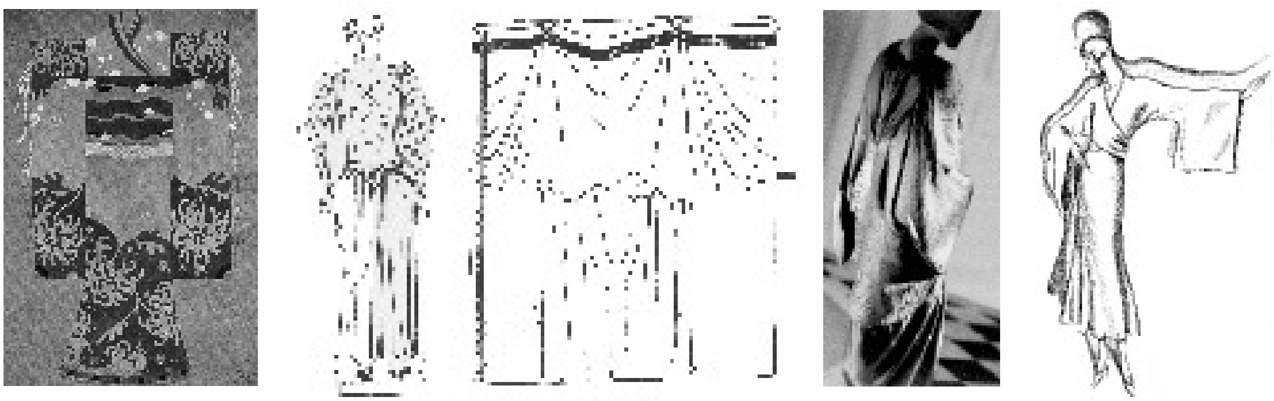
Clothing is typically regarded as one of the necessities for human survival, along with food and shelter. In the primitive era of man, the development of clothing as a protective barrier against cold, rain, snow, and abrasion was linked to the invention of other tools: clubs to kill animals for meat and fur, awls and sinew for connecting pieces of material. Over millennia, developments in technology, the organization of societies, politics and religion have all had a part in clothing's evolution from this most basic need to the socially and emotionally loaded commodity it is in modern times.

Throughout history, people of all cultures have adorned themselves. Apart from its practical function as covering and protection, clothing has served to distinguish people socially, economically, and culturally. Modes of dress distinguished monks from peasants from kings. Before the advent of machines, "fashion" was exclusively limited to the elite few who could afford to have beautiful clothing made for them by professional clothing artists; in this regard, it served as a means of expression for the rich and noble, and a socioeconomic indicator for everyone else. Irish fisherman traditionally wore sweaters knitted in patterns representing clan and home, while Guatemalan textiles included symbols encoding home village, marital status, social standing, etc. (Siegel, 1999).

Mechanization of textile production during the Industrial Revolution, the expanding range of qualities and prices of fabric, and socially leveling and political change after the French Revolution, engendered a fashion industry that provided choices of clothing to all classes of society (Bernier, 1989). Textile production was one of the driving forces behind the Industrial Revolution, as evidenced by the invention of the cotton gin in America (by Eli Whitney in 1793), the flying shuttle (John Kay in 1733), the water frame (Richard Arkwright in 1775), and the spinning jenny (James Hargreaves in 1764). The steam engine's invention allowed the powering and integration of these advances, and the first factory with all the processes for making cloth under one roof was built in Waltham, Massachusetts in 1814. The availability of fabric, and the invention of the overhanging-arm sewing machine by Isaac Singer in 1851, made the process of making clothing faster, cheaper, and more readily accessible. The invention of numerous washing machines from 1797 to 1850 made the care of garments more accessible as well (Compton's, 1997). No longer restricted to the wealthy, choice in clothing spread to the masses. Today the fashion industry is international. Hundreds of thousands of styles can be purchased "off the racks", at every price level, in any size. With a huge variety of clothing available to almost everyone, what we wear today is much more of a personal choice than an economically- or socially-driven necessity.

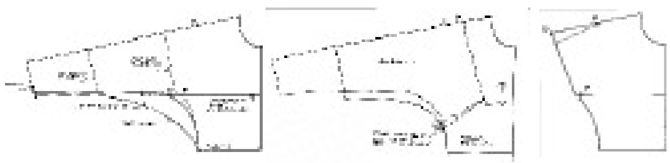
Garment Construction

The design of a garment from flat cloth, that covers a three-dimensional body securely but flexibly, with aesthetic appeal, is an engineering and design problem that has been solved in numerous ways.



From left, block print of a Japanese Kimono; Greek chiton; chiton structure, essentially a rectangle of fabric sewn into a tube, fastened at the shoulders, and tied at the waist; Kimono-inspired cloak, Callot Soeurs, 1920-23; sketch of a dress with dramatic kimono sleeve, Vionnet, 1922.

Wrap-and-tie techniques, exemplified by the Japanese kimono and Chinese robes, utilize fabric most efficiently, with the least amount of cutting. They have their roots in the earliest garments made from woven fabric, which were never cut to shape but draped and tied at the waist. This type of draped garment was worn by the early Egyptians; the chiton of the ancient Greeks and the toga of the Romans were also draped (Compton's). The shape is loose and voluminous, fitted to the body by tying or tucking. Such historical garments are the precursors to today's bathrobe and lounging jackets, and have also been interpreted by modern Western fashion designers. Especially in the 1920s, kimono-style sleeves and the loosely wrapped "cocoon" coats of French designer Paul Poiret were fashionable. The kimono sleeve, with a rectangular sleeve and straight, rather than curved, armhole, has inspired other sleeve styles that are cut as a single piece with the bodice: the dolman, capped, drop-shoulder, or batwing sleeve. (Stringer, 1992).



Above, sleeve patterns, from left: batwing, dolman, and cap. Pamela Stringer, 1992.

Below, "dart pivoting," a technique for manipulating flat paper patterns. On the left piece, shaping for the bust is provided through a dart from the shoulder. To move the dart, a line at the new position is drawn. The pattern is cut along this line and pivoted, folding the original dart closed and opening the new dart. This method is also called the "slash-and-spread" technique.

Western silhouettes, with more tightly fitted garments, are created from much more complex shaped flat pieces, which form a three-dimensional shape when sewn together. The design of flat patterns -- the shape of pieces, the placement of seams -- is a technological art that involves geometry, knowledge of material (fabric), and aesthetic design. The use of predrawn patterns, as opposed to creating garments on a body, dates to as early as the 12th century, when Italian monks made a back and a sleeve pattern from slate to be used by those in the monastery and the people under their protection. The idea could have come from Greek merchants who would have traveled from Egypt (Stringer, 1992). By the middle ages a crude form of dressmaking had been developed in France, and by the 15th century much more shape had been introduced. In 1671 a book on pattern cutting was on sale in Paris, written by a master tailor. Home sewers could cut pieces of cloth to shape based on the measurements of the body. Paper patterns, which are pre-printed on tissue in standardized sizes and used to guide cutting, were invented in the 19th century by Ebeneeza Butterick, whose company continues today.

Paper patterns themselves derive from the simplest fitted form, the sloper. A sloper is drafted based on body measurements; the technique of translating bust, waist, shoulder, and other body measurements into pattern shapes is one that has been refined over centuries. On a basic sloper, shaping is introduced in the form of shaped seams and darts: angled seams which, when sewn together, create volume. Pattern drafting techniques involve the manipulation of the basic sloper pattern to achieve various silhouettes and detail: full skirts, billowing sleeves, bustles, ruffles. Flat pattern drafting allows the creation of new styles on paper, which can be fine-tuned on a dress form without starting from scratch. In the fashion industry, designers sketch garments and the sketches are translated into garments by cutters, experts in pattern drafting.

For some couture designers, an often-preferred technique for shaping flat fabric to the body is that of draping. Fabric is draped onto a dress form, folded and pinned into place, and pattern lines marked. When the fabric is unpinned, the marked seams form the flat pattern. Some of the greatest designers of the 20th century designed through draping, most notably Madeleine Vionnet, who is credited with discovering the bias. Her method of designing was to drape very fine silk organza on a quarter-scale human figure (Kirke, 1998).

Left, Madeleine Vionnet draping muslin on a quarter-scale mannequin. Right, a 1930 gown by Vionnet molds to the body and falls in liquid folds due to its cut on the bias (photograph by Hoyningen-Huen).

Most loomed fabric is made up of two sets of threads (warp and weft) woven at right angles to one another. If a piece of fabric is pulled along the line of the threads – “on the grain” – it is strong and firm. At an angle to the threads, the fabric stretches. “True bias” is at a forty-degree angle to the grain. Clothes are traditionally cut on the grain, with the warp running vertically and the weft horizontally on the body, resulting

Pleats create expandable volume in a garment from Issey Miyake's Pleats Please collection.

in a sturdier garment that does not stretch out of shape. In working and draping fabric on miniature dress forms, Vionnet exploited fabric's stretch on the bias to create dresses that molded to the body without darts: the bias cut.

Pleating is another way of introducing greater elasticity, and therefore shape, into fabric. In the 1910s and 20s Mario Fortuny used a secret technique to permanently press fine silks into thousands of narrow pleats. His Delphos gowns, created from his pleated silk, molded to the body without darts and shimmered in the light. Today, Japanese designer Issey Miyake offers a collection of similarly-pleated silk garments, by the name of Pleats Please. The elasticity of the pleated fabric is used not only in slim fitted designs, but also in bolder geometric silhouettes and volumes.

The seam itself is not only a construction element which joins pieces of fabric together, it is also an aesthetic element in terms of its placement and finishing. So-called "style seams" are those which are purely aesthetic, providing no extra shaping to the garment. Cowboy shirts often have elaborately-shaped yoke seams: scalloped, angled, or the

Five frontier shirts from Folkwear Patterns feature elaborate yoke and closure details, from left: scalloped, bull's head, lace front, angled bib, and rounded bib.

traditional "bull's-head" yoke (Folkwear, 1999). Yves Saint Laurent's famous "Mondrian" dresses and other Op-Art clothing of the mid-1960s employed seams to piece contrasting colors of fabric together. Seams can be sewn by machine or hand, in a huge variety of stitches: straight stitch (basic seam), invisible hem (for the edges sleeves, necklines, etc.), flat-fell (for denim and other heavy fabrics), french (for lightweight, sheer fabrics), hand-rolled (for very fine hems), faggoted (leaving small decorative gaps), and basted (long temporary stitches, for fitting) are only a tiny selection of commonly-used stitches.

Means of closure is similarly both aesthetic and structural. Ties, buttons, and pins have existed as fastenings since ancient times. Prehistoric garments were sometimes fastened with thorns, the ancestor of the pin and needle. Buttons paired with buttonholes appeared in the early 15th century. Coil zippers were patented in 1912, and velcro in 1948.

Perhaps unique to fashion is the property that such discoveries, developments, and techniques in clothing construction are not necessarily evolutionary steps towards an ultimate goal, but rather expansions of the vocabulary of dress. The kimono, the bias, and the dart are all elements of this vocabulary, stylistic elements which coexist within the greater realm of clothing, affording a wealth of choices to the individual.

Materiality

To both designer and wearer, construction and material are of equal importance in clothing. Fabric technology has been constantly progressing, both in terms of textile production and in fiber development. The oldest known materials are furs and skins, which were first stripped from killed animals. Tanning, in which hide is treated with an infusion of tannin-rich bark or other agent in order to render it more supple and durable, was gradually discovered as a way to make skins more wearable. Buckskin and deerskin are the traditional materials for Native American clothing. Leather is most commonly used in shoes, boots, purses, luggage, and jackets in the fashion industry because of its durability and protectiveness.

Woven fabrics, or textiles, originated as early as 6000 BC (Compton's, 1997), as people began to farm and then to raise animals. Wool from sheep and fibers from the flax plant could be twisted into yarn, which was then woven on a primitive loom into rectangles of cloth.

Silk has long been the most precious and luxurious fiber, discovered around 1500 BC when the Shang people of China learned to cultivate the silkworm, the larvae of the moth Bombyx mori. Silk is the solidified protein secreted by the insect in order to create its cocoon. Silkworms live solely upon a diet of white mulberry, which is native to China. According to legend, a cocoon accidentally fell into the tea of an empress and the fibers, moistened and loosened by the hot liquid, came away in a long fine strand as she drew it from her cup (Feltwell, 1990).

Silk fabric is lightweight, warm, strong, and possessed of a beautiful lustrous sheen, making it the chosen fabric of emperors, queens, popes and nobility. Over the centuries, advancements of sericulture and weaving technology make it available, but it is still the most expensive natural fiber.

The popularity and beauty of silk prompted the English naturalist Dr. Robert Hooke to remark in his book Micrographia, published in 1664, that it should be possible to make a glutinous material similar to the excretions of the silkworm, in order to create fibers. With these words, Hooke foreshadowed the prominent role of chemistry in contemporary fabric technology. Viscose Rayon, or "Artificial Silk," was the first man-made fiber and appeared in 1885 after numerous attempts by chemists to create an artificial fiber. Based on cellulose, the natural polymer derived from woody plants, viscose fibers were twisted into yarn and woven or knitted into fabric. The man-made fibers could soon be produced more cheaply than natural fibers, and soon inexpensive stockings, underwear, hosiery and dress materials were being made of rayon (Handley, 1999).

The use of rayon and other synthetic materials was embraced by only a few adventurous couturiers in the early years, as natural fabrics were still revered as the most comfortable and highest quality. Nina Ricci designed a black cellophane coat in 1935. Elsa Schiaparelli, whose eccentric flair linked her with Dali and the Surrealists, was more enthusiastic about the new materials. She collaborated with the French textile company Colcombet to experiment with the newest and most unusual man-made materials: perspex, lucite, plexiglass, and cellophane. Her "glass cape" of 1934 was created out of a transparent brittle material called Rhodophane (Handley, 1999).

Glass Cape, 1934, by Elsa Schiaparelli. Schiaparelli had close ties to the Surrealists, most notably Dali, as well as communities of artists who introduced her to new materials such as the rhodophane for this garment..

Models demonstrate the strength of nylon stockings at the Word's Fair in 1939.

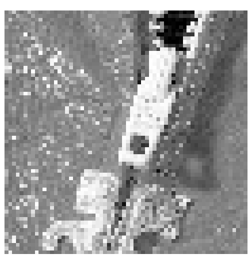
In 1938, the vice president of Du Pont announced "a new word and a new material: Nylon." Nylon was, as he explained, a filament "strong as steel yet fine as a spider's web," and the "first man-made textile fibre derived from coal, water, and air." The technological basis for nylon is polymer chemistry, in which infinitely-long molecules (polymers) are created by chaining smaller molecules together. The first long-chain polymer fiber was pulled from a beaker in 1934, by an MIT graduate Julian Hill under the direction of experimental scientist Dr Wallace Hume Carothers (Handley,1999). Textile World gave the following description of nylon's chemistry:

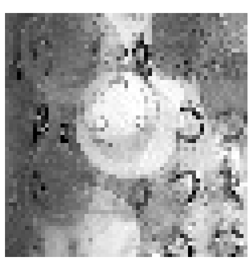
> "Nylon is made by heating the proper intermediates -- a dibasic acid and a diamine, for example -- at a temperature somewhere between 400 and 600 degrees Fahrenheit. When that is done -- and here you have the secret of Nylon -- the molecules begin to hook themselves together in long chains. Nylon is first formed in icy-white ribbons of any width and thickness that happens to be convenient for handling in the factory. If intended for use as a textile fiber, these ribbons are broken into little chips. The chips are water-clear liquid, looking like thick glycerine, is squirted through tiny nozzles to form cobwebby filaments, which solidify in the air and are wound on spools ... stretching makes Nylon stronger." (Wharton, 1938)

Nylon was immensely successful. American women clamored for nylon stockings, and department stores reported riot scenes. With the outbreak of World War II, the subsequent rationing of fabric (including nylon) only whetted the appetites of consumers as well as designers and left them eager to adopt nylon when it became widely available after the war.

The sixties was a golden era for all technological materials and, in particular, a boom period for synthetic fashions. Man-made materials were considered avant-garde by couturiers and young anti-establishment boutiques alike. Plastic was used in clothing and accessories, from Paco Rabanne's 1966 dresses made from linked discs of colored plastic, zippers made of plastic instead of metal, and early fiber optics incorporated in a sleeve embellishment (Handley,1999). Polyester was the fabric of the seventies, and man-made fibers, pure or blended with natural fiber, are a matter of course today.

Fabric technology continues to advance, with high-performance sport and safety fabrics developed by companies such as 3M and Gore-tex, and appropriated by designers from Donna Karan to Miuccia Prada. Highly reflective fabric, created by laminating thousands of tiny spherical glass lenses to a base fabric, was originally developed for road workers to provide high visibility, but has also become a popular embellishment on logo t-shirts, jackets, shoes and pants. Unique textures may appeal to consumers: Kevlar, the material of bullet-proof jackets, shows up in New York boutiques along with Teflon and Astro-Turf. Fashion designers are exploiting the allure of a "high-tech" fabric at the turn of a new century, as well as consumers' desire for apparel that combines high performance with high style.




Clockwise from top left: a sleeve with fiberoptic detailing; plastic zipper; Paco Rabanne's 1996 dress made up of linked plastic disks; detail of Rabanne dress; plastic telephone wire fringe.

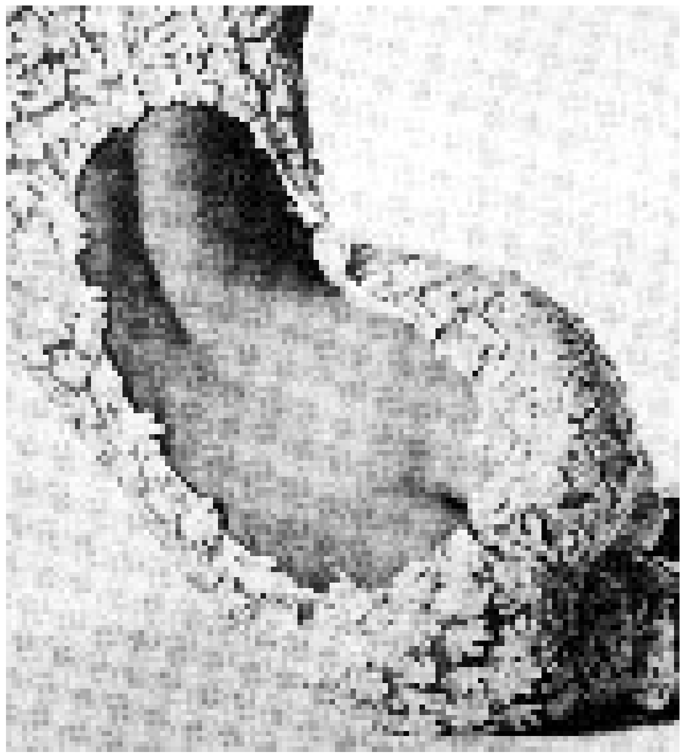
Clothing as Ornament and Display

The fashion system is one in which ready to wear apparel is available in a vast array of styles, sizes, and price ranges. Most people have a choice about what they wear.

The vocabulary of fashion, or the range of elements that make up a garment, encompasses all types of aesthetic form and ornamentation. Native Americans use feathers and elaborate beadwork applied to deerskin and other leathers. The seminal Hollywood fashion designer, Adrian, embellished dramatically-draped gowns with jewels, rhinestones, and glittering star-shaped sequins to establish the glamour of the movies in the 1930s (Lee, 1975) . At one point in 18th-century Paris, "canes with gold apple heads" were a popular trend (Roche, 1994). Fabric, beads, feathers, dye, and jewels are the media, and shaping processes such as wrapping, seaming, and draping the techniques that a fashion designer employs to create a beautiful, distinctive garment.

A man in New Hebrides wraps his penis in cloth to form an impressive bundle.

Just as the brilliant plumage of male birds-of-paradise serve to attract members of the opposite gender, clothing is often a means of displaying sexual desirability. In fact, ornamenting the body to enhance desirability has been a fundamental function of clothing from the start. Traditional Zulu beadwork incorporates complicated color and shape codes for displaying tribal affiliation, marital status, or "love messages." In parts of Papua New Guinea, men cover their genitalia with elaborate bamboo covers up to 15 inches long and adorned with teeth, feathers, shells, and paint in order to impress women and enemies with the wearer's virility (Rudofsky, 1971). In Europe during the 15th century, the codpiece served a similar purpose. The Padaung women of Myanmar are famous for using stacks of metal neck rings to elongate their necks, a sign of beauty. In China, small feet were considered beautiful because of their connotation of aristocracy, and foot-binding was in practice from the 10th century until 1911, when it was banned by the new Chinese republic. Delicate hands and feet, evidence that a woman has servants to do the hard labor, have traditionally signified wealth and high class, and have been emphasized through such articles as kid gloves and the ever-popular stiletto heel. Clothing figures prominently in rites of marriage as well. The traditional Western white bride gown is a symbol of the bride's virginity. The veil, a female accessory in many cultures, implies modesty. The cocktail dress, a staple of the 1950's in America and epitomized by Audrey Hepburn's Givenchy-designed "little black dress" from the film Breakfast at Tiffany's, evolved as a semi-formal dress for attending cocktail parties, common gatherings for meeting interesting new people of similar social standing. Even aside from specifically-assigned clothing types, fashion in general is often a means to appear more attractive to others. By controlling our outward appearance, we create visual impressions of ourselves for others to interpret.



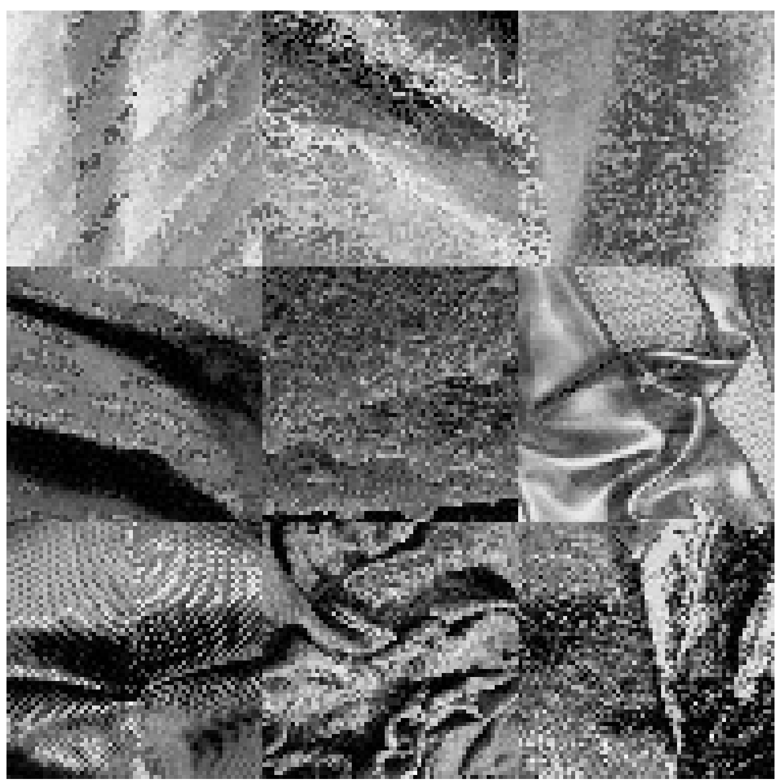
Right: the strategic cutout in this Ungaro dress from 1960 draws attention to the small of the back as an erogenous zone.
Lower right: cocktail suit, gloves, and a hat by Jacques Fath, 1951.
Below: footbinding, the crippling and stunting of women's feet in order to keep them tiny, was a sign of daintiness and aristocracy in China.

Clothing as Architecture

Fashion is most often regarded as an outward expression of self, even vanity. All too overlooked are the various sensations, not only visual, affected by clothing on the body.

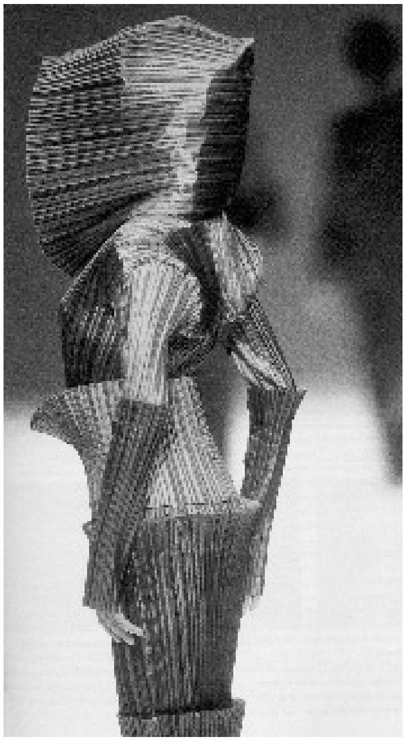
Touch

Fur and leather are prized today for their durability and warmth as well as their beauty and luxurious textures. Buckskin, especially prized by Native American tribes, is light and buttery-smooth. Mink and ermine, classic luxuries for royalty and the very wealthy, are fine-grained furs that provide soft, glossy warmth. Selection of fabric is often based on tactile properties. Charmeuse, a liquidly-draping satin, is smooth and cool to the touch, while the mohair sweaters made popular in the 1960's is soft, fuzzy and warm. Against the skin constantly throughout the course of a day, clothing provides perhaps the most persistent tactile stimulation.



A selection of modern Japanese fabrics demonstrate the wide variety of fabric textures.
Top row: "Combed Paper," "Frazzled Paper," "Turkish Wall."
Middle row: "Graphite," "Jellyfish," and "Stainless Series." All by Reiko Sudo for Nuno, 1990-1997.
Bottom row: 100 percent polyster fabric examples, Junichi Arai, 1997.

Space



A jointed garment by Issey Miyake differentiates spaces on and around the body. The large cantilevered hood provides deep shade to the wearer's face.

Clothes may mold closely to the body like a second skin, or create space around it. In even fitted garments, it is customary to add "ease," the extra space that allows for movement at the limbs and waist. Without ease, garments can become constrictive, tight and cramped containers for the body; the corset and brassiere are prevailing examples of the restrictive garment. Body-skimming or revealing garments might provide an enhanced awareness of one's own body, as in Rudi Geinrich's notorious 1967 monokini. Clothing that stands away from the body can emphasize the body itself as well, as in wide funnel-neck coats that draw attention to the slender throat rising upwards. In a "cocoon" blouse by Isabel Toledo, sleeves hover above the shoulder, creating an almost spherical space at either side of the body. Hoods likewise enclose the head while providing space for movement and vision.

Light

The manipulation of light is also the provenance of fashion. The most sumptuous silks and satins are immediately discerned by their luster, the smooth play of light across their surface. Transparency, the transmission of light, appears in the sheerness of organdy ball gowns, the delicate perforations of lace, and strategically-positioned cutouts that form windows upon the body. Hoods, visors, wide-brim hats, and tinted lenses provide shade to a normally exposed area: the face. Meanwhile, ornamental devices such as sequins, beads, and metallic fabrics "catch light," sparkling and glittering.

Nomad

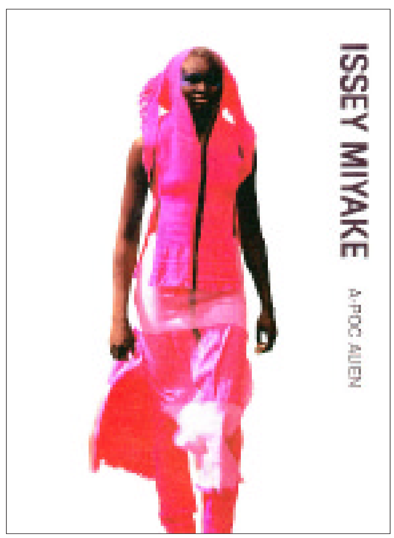
Clothing encloses not only our bodies, but our possessions as well, enabling us to maintain a constant set of tools, talismans, and information as we move from place to place. Claire McCardell was a particular promoter of pockets in women's clothing in the 1940s, including generous pockets in all her garments, even bathing suits and evening dresses. For the pocketless woman, purses provide storage for on-the-go necessities and personal items. Especially in the later half of the 20th century, the market for luxury purses and handbags has become competitive, with fashionable designer lines such as Gucci, Prada, and Hermes commanding astronomical prices and long waiting lists. With "future" often associated with "mobility" at the turn of the century, sporty backpacks, carryalls, arm and waist pouches are as stylishly designed as shoes and dresses. The Japanese company FinalHome's signature item is a waterproof jacket whose surface, including the hood, is entirely lined with pockets to provide safekeeping for all of the wearer's personal possessions. Alternatively, "newspaper can be inserted into the pockets for warmth." Price tag notwithstanding, the garment responds to the plight of homeless urban nomads in a dystopian future.

Final Home's transparent pocket jacket stores and displays personal possessions, 1999.

Through fashion, we build personal architecture on our bodies and carry it with us as we move in the world; our garments define a personal space with persistent sensual stimuli: the feel of scratchy wool against skin, the restrictiveness of narrow armholes, the shade of a hood, the gape of a neckline, the clink of bangle bracelets, the sparkle of a ring or the zip of corduroy pants. Under extreme or hazardous conditions, clothing may replace shelter, becoming a portable home and base of operations.

Mutable Clothing

In a departure from designer or tailor-dictated styles of the past, the concept of customizable or mutable garments has been explored by modern designers in recent years. These clothes function as many-in-one garments: reversible raincoats with a bold pattern on one side and solid color on the other; Ba-tsu pants with zippers for conversion into shorts or knickers; a single Toledo pattern that yields five different blouses depending on how the fabric is folded; Triple Soul's coveralls that collapse into a backpack. Alternately, they provide basic structures for creating personalized individual garments. In the 1980s, the brand Units offered unisize knit components that could be combined in different ways to create a myriad of garments from the basic kit of bandeaux, tubes, sashes, and shifts. With his "A Piece of Cloth" (APOC) line, Issey Miyake has designed a one-size-fits-all tube of fabric with special seamlines and areas which can be cut or not, according to the wearer's design. A single tube provides dress, gloves, hat, pouch, undergarment, and socks. The dress can be cut apart into a shirt and skirt; sleeves can be cut to any length; skirt can be cut to any length; shirt can be cut open into jacket; hat can be attached as hood. Such user-end choice allows the wearer to be the final arbiter of the garment's design, rather than a consumer of ready-to-wear per se. Fashion has moved away from the prescribed-style hierarchies of yore to a more open field for personal expression and individualization.



"A Piece of Cloth" (APOC), Issey Miyake, 1999.

The Psychology of Fashion

Fashion articulates a tangle of social, economic, political, and emotional considerations. Every choice seems to be loaded: are black trench coats depressed or disturbed? Is lace weakly feminine? A pinstripe suit aggressively male? The way we decide what to wear can be a complex and twisted path.

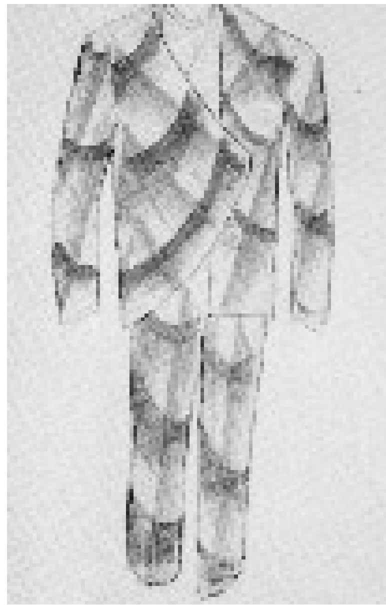
Socially, fashion can differentiate as well as homogenize. Once the sole province of people who were wealthy enough to pay for fine fabrics, tailors, and dressmakers, fashion has always been a "status" indicator. When fashion became available to ordinary people after the French Revolution, people's first instincts were to imitate the styles of the aristocracy, to give the impression of belonging to the "higher class." The businessman's suit and tie marks him as being of a certain economic class:

white-col.lar \'hwi-t-'ka:l-*r, 'wi-t-\ aj : of, relating to, or constituting the class of salaried employees whose duties call for well-groomed appearance

blue-col.lar \'blu:-'ka:l-*r\ aj : of, relating to, or constituting the wage-earning class

Uniforms create an egalitarian environment peopled by a collection of surface-undifferentiated workers. Similar dress in social situations signifies group affinity or kinship, common taste and status. Social dressing is a precarious balance of conformity and individuality, with the aim to render one's appearance similar but slightly different -- same cuts, mutually sanctioned designers, same palette, but never the same outfit, which is the ultimate faux pas.

In contrast, "anti-establishment" or "alternative" dressing seeks to set people apart from whatever the "norm" is. In the 1920s, "avant-garde" artists adopted modes of dressing based on their artistic philosophies; Giacomo Balla distributed a manifesto on il vestito antineutrale, "anti-neutral clothing." Artists showed their nonconformity through asymmetrically-cut garments, bright colors, accessories with flashing lights, aluminum "anti-neckties," and metal shirts (Buxbaum, 1999). Similarly, the Punk attitude of making one's own clothes (and music) as an angry shunning of adults by youth, was manifested through dark, torn



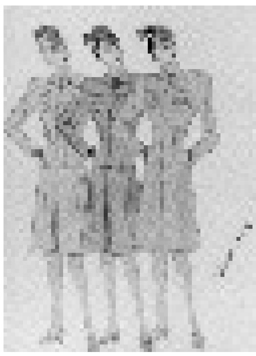
Left: a bold, multicolored Futurist suit design by Giacomo Balla, 1913-14. Right: this New York woman wears an eclectic and unorthodox mix of punk and glam clothing.

clothing, t-shirts scrawled with confrontational statements, safety-pinned tears, drainpipe pants (narrowly cut pants which were a reaction to hippie bell-bottoms) and razor blades (Buxbaum, 1999).

In adolescence, when the desire to "fit in" typically reaches its peak, the clothing can be especially significant. The varsity football jacket, cheerleader's uniform, and prom dress are all symbols of American high-school nostalgia. After the Littleton, CO tragedy in 1999, in which a pair of black-trenchcoat-clad teenage boys shot and killed 12 classmates and teachers, the black trench coat was pounced on as a symbol of alienation, waywardness, and even violence by schools and the press nationwide. So strong was the association with delinquency and violence that several schools banned the wearing of black trench coats. How does an article of clothing gain so much emotional and political baggage? When does a person become symbolized by a garment?

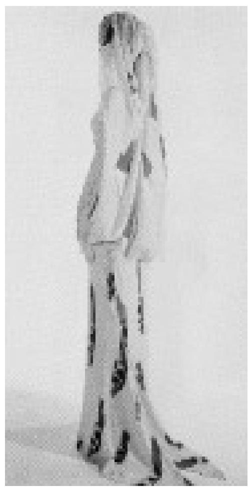
People who love clothes and own a plenitude of garments run the risk of being regarded as vain and frivolous. When Ferdinand and Imelda Marcos fled in shame from the Philippines, the over 200 pairs of shoes discovered in Imelda's closet sealed the fate of this pair to be publicly vilified as plunderers of an innocent nation. The shoes had been purchased with money embezzled from the Filipino government. Yet even for non-embezzlers, owning an extensive wardrobe or taking pleasure in beautiful or luxurious garments is apt to invite reproach. An anecdote from Andrea Siegel, taken from her book Open and Clothed, provides one perspective:

> The seed for this book was planted on a cold spring day in Boston in 1982, as the clear afternoon light slanted through the venetian blinds in my Italian professor's office. For a moment I looked up from my textbook and admired his attire. He, a kindly elegant gentleman of perhaps fifty, with a shock of white hair and a goatee, wore a simple wool sweater and a pair of wool pleated trousers and loafers. Color, weight of fabric, texture, and cut blended into a gift to the eye. His sweater fit him perfectly and was always in some subtly altered shade, perhaps still blue, but a grayer blue than expected, or a brown with some green His trousers were also of extraordinary fabric, and his shoes were beautifully yet simply designed. I asked him the question that preyed on my mind: "You always dress beautifully, and what is that all about?" After thinking for a moment, he responded seriously: "I am flattered and also embarrassed by your compliment. Thank you. I will tell you. I knew from an early age that the work can be a terrible place. In the war - World war II - I saw things so terrible I cannot mention them here. I realized then that if there are simple things I can do that can make life easier for other people, these things I will do. Among them, I dress so that people will look at me and see something pleasant to look upon, perhaps beautiful. So much of life is difficult. I want to do a small kindness. It is important to bring harmony and beauty back to this troubled world. I do not feel I am the most beautiful person on earth, but rather that it was important to me to give in this way, to know that I am making contributions."



Wartime fabric shortages and military influence prompted the narrow, straight-shouldered dresses of the 1940s (top). In contrast, the Christian Dior gown of the 1950s celebrated post-war abundance and an eager return to femininity (above).

Indeed, human responses to events and movements in the world have often been reflected in fashion. During World War II, silhouettes were narrow because of fabric rationing, and women's fashion designers appropriated details of work and military uniforms, as women themselves mobilized as the domestic workforce to replace men sent to war. Nylon stockings were willingly sacrificed to serve the patriotic cause, and women resorted to dyeing their legs or painting vertical stripes to simulate the seams of sheer hosiery. After the end of the war, demand for nylon stockings was greater than ever, and women reveled in the twenty-yard gathered skirts of Christian Dior's "New Look" fashions, abundances of fabric bursting from tiny waists into voluminous folds. In the 1960s, space travel captured the imagination of the public as NASA and science strove to put a man on the moon; this excitement was



Counterclockwise from lower right: Pierre Cardin's 1966 Cosmonaut collection; an Op Art bathing suit from 1966; a trompe l'oeil "tear" dress and veil by Elsa Schiaparelli, using a motif by Dali, 1937; spaceage suit and helmet hat, Cardin, 1996.

reflected in many designers' fashions from that decade. Emilio Pucci, the Italian designer famous for his brightly-colored printed fabrics, was commissioned to design stewardess uniforms for Braniff Airlines, and included transparent "bubble helmets" reminiscent of astronaut space suits. Similarly, Courreges prescribed "go-go boots," inspired by moon boots, for the earthbound space explorer, along with short mini-shifts emblazoned with cosmic insignia (the shape of the Star Trek symbol, before Star Trek). Fashion has incorporated the ideas of art movements as well. Elsa Schiaparelli collaborated frequently with Surrealist artists like Salvador Dali, with whom she created a famously elegant gown decorated with a lobster. The simple shapes of so-called "shift dresses" took on modern energy when pieced from black, white and brightly-colored fabrics in the visual patterns of Op Art and Mondrian in the 60s.

Fashion is an outlet, a medium, a canvas for personal expression.

Techno-style and Smart-wear

Researchers at the MIT Media Lab double as computer-augmented cyborgs, sporting miniature displays positions over one eye for constant visual input (photo: Sam Ogden).

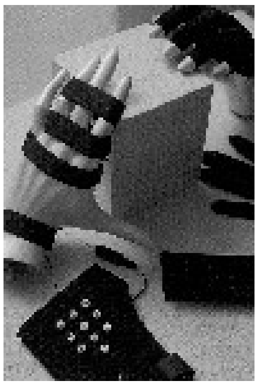
The incorporation of electronics into garments is a burgeoning enterprise that has been sparked by technological advances that make electronic and computing devices smaller and more wearable. Especially with the proliferation of cell phones and PDAs (personal digital assistants) such as the Palm Pilot, the migration of computers from the desktop to the body seems more and more viable. Margaret Orth at the MIT Media Lab has helped develop methods for stitching electronic circuits directly into fabric, using conductive fibers (Orth, 1997). The miniaturization of computers, displays and input devices have enabled the design of wearable "augmented reality" systems consisting of portable computers, one-handed "twiddler" keyboards, and eye-mounted miniature displays (Starner, 1997). Whereas the proposition of technology in clothing once evoked images of James Bond and espionage, today's visions of gadgetry-infused clothing speak more of cyborgs or one-man information stations.

Inevitably, technologies will become even more flexible, smaller, faster and cheaper. Their use as aesthetic fashion elements in the tradition of sequins or stripes, rather than portable devices (personal digital assistant, cell phone, email inbox), has already begun. Orth's research

Left: Erina Kashihara's illuminated skirt on the cover of Object Magazine, February 1999. Right: Thierry Mugler plastic jacket with circuit-inspired pattern, 1991.

included the Firefly Dress, with dozens of blinking LEDs applied bead-like to metallic organza. Walter van Beirendock, designer of the youth-geared clothing label W&LT (Wild and Lethal Trash), used a row of flashing red LEDs on the front of a t-shirt in his winter 1997-98 collection "Avatar" (Van Beirendock, 1997). Indeed, along with the use of metallic silver, the blinking LED has become a kind of pop-culture symbol of technology, associated with robot eyes, indicator lights, and Kit's "talking" hood in the classic television series "Knight Rider." Fashion has historically loved to play with light; sequins, beads, and small pieces of mirror are ways of catching and reflecting light as ornamentation. The ability to emit light is evocative and has been used in experimental garments by artists and designers. Maya Arazi, Merav Levi and Zuri Gueta have made an "Illumination" dress out of neon fibers and polyester (Handley, 169). Erina Kashihara has constructed a cage-shaped skirt sprouting small glowing spheres (Whish, 1999). Although the concept of light-up clothing seems outlandish to many, youth club culture is already embracing novelty tshirts with designs that flash in different patterns, controlled by a simple microchip.

There are also examples of computation as an expressive element of fashion. The computer revolution has already influenced fashion. Computer-generated graphics, including fractals, manipulated imagery, and 3D graphic landscapes, appear on t-shirts, accessories, and textiles. Even the motherboard itself is an inspiration -- in 1999 Thierry Mugler produced plastic jackets printed with circuit-like tracery (Handley, 1999). Real-time computational behavior on clothing exists primarily on watches and novelty accessories. Examples are a Casio G-Shock Mixmaster watch that plays tunes in user-configurable sequences, and a Citizen Pop Watch that lights up in response to arm movement. Casio also recently announced the production of watches that with embedded cameras. More interactive, multi-wearer instances are the MIT Media Lab's "MEME tags," small badges that store personal information about the wearer and detect the presence of another badge containing similar data (Borovoy, 1996); a similar idea appears in Philips Electronics' concept of "Hot Badges," meant for uniting potential partners (Philips Electronics, 1996).



Prototype "glove telephones" designed by Lorna Ross at the Royal College of Art, 1994.

The Design Space of Computational Fashion

These are some of the parameters of computational fashion, common themes that provide a basis for discussion and comparison of technologically-enhanced clothing. While the evaluation of a garment ultimately tends to be subjective, these axes represent ranges of qualities within which specific pieces might be positioned and contextualized.

Ornamentation

Is the design of the garment based on functionality or visual or tactile impact? To what extent does it serve an aesthetic purpose? At one

ornamental  *nonornamental*

extreme might be the white cotton sweat-absorbing athletic sock sold in packs of twelve. At the other would be jewelry. Despite the association of ornamentation with beauty, fashion trends do not necessarily dismiss practicality from the realm of desirability. Jeans, developed by Levi Strauss as durable work clothes for manual laborers, have become a staple of most people's wardrobes. Similarly, the popularity of the movie "Flashdance" in 1983 turned leg-warmers and sweatbands into must-have fashion accessories.

Practicality/Necessity

The protective or strictly utilitarian qualities of a garment. Most garments conceal or cover the body to some extent. Wristwatches, space

practical  *nonutilitarian*

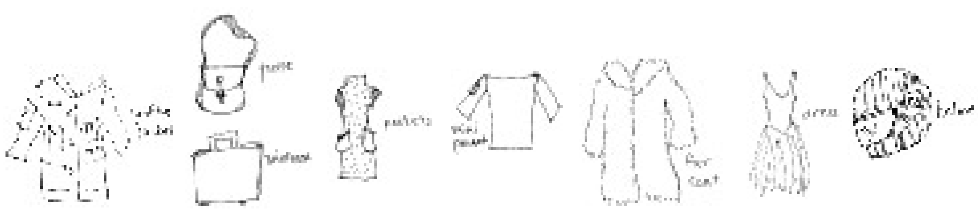
suits, football uniforms and weatherproof outerwear would fall towards one end of this axis, opposite from fishnet stockings and lace collars.

Road workers’ highly reflective uniforms protect by alerting oncoming cars to the wearer’s presence, rather than through a direct physical shielding. Although garments that are not ornamental tend to exist for practical reasons, the two axes are not inverses of each other; highly protective clothing can also be highly ornamental, such as elaborately-tooled armor or inlayed cowboy boots.

Storage/Mobility

The ability to store things in a garment, which in turn facilitates mobility. Pockets and hooks or loops allow storage to be incorporated into any type of garment - pants, dresses, shirts, outerwear - while purses and backpacks are specific storage accessories. Being able to carry possessions and tools on one’s person helps to establish an immediate local environment with tools, talismans and information at hand even while in transit. Bicyclists’ shirts include pockets for water bottles, positioned at the lower back for easy access while biking. In contrast, most women’s evening dresses lack pockets, necessitating the use of a purse or the entrusting of one’s valuables to an escort. As with any fashion attribute, details designed for storage can be assimilated by the

capacious/
mobile



storageless/
encumbering

fashion world as aesthetically desirable; witness the sweater and shirt adorned with pockets too tiny for anything but candy or small change. With the incorporation of electronics into clothing, mobility is an issue in terms of how much electronic elements are actually designed as wearable parts of the garment, versus being “black boxes” that attach or tag along with the body. Taking portable audio as an example, boom boxes, though portable, are bulky objects that must be carried, whereas the walkman is designed specifically to be worn on the body as it moves.

Communication/Identification

Although any clothing can be construed as an expression of personality or identity, certain garments are more explicit when it comes to communicating something about the wearer. Uniforms indicate membership in a group or team (school, sport, workplace), and are often even emblazoned with the wearer's name or initials. Traditional garments and fabric patterns can be coded with designs signifying birthplace, clan or family, as with Scottish tartans. Marathon runners often write their names, nicknames, or hometowns on their singlets so that onlookers can cheer them as they run.

meaningful/ transmitting

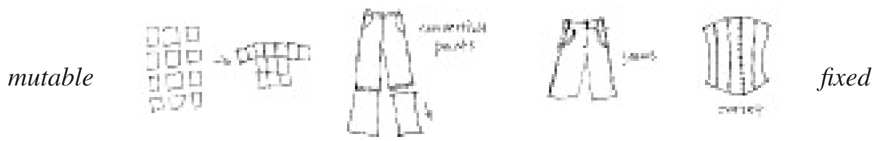
impartial/ mute

On the other hand, anonymity may be attained through the use of generic, nondescript or very common clothing, such as the khaki trench coat. At the most extreme, clothing may become a disguise, or a way to hide personal information. Masks are specifically concealing, but uncharacteristic clothing can also be used as a deceptive or evasive means (Tony Curtis and Jack Lemmon's characters dressing up as women in the movie "Some Like it Hot").

With the incorporation of electronics into clothing, modes of communication through fashion are extended further. Lorna Ross's models for telephone gloves allow explicit communication through actual conversation. The MIT Media Laboratory's MEME tags transmit information about the wearer to other tags. Cell phones and beepers themselves have entered the realm of fashion: in Japan, an incredible array of cartoon-character pendants, flashing antennae, and sleek pouches are available for embellishing cell phones, while both cell phone and beeper manufacturers strive to design attractive and trendy cases for the devices. Traditional fashion allows people to express themselves and communicate personal information to the general public; electronics allow targeted communication of specific data to specific people.

Mutability/Reconfigurability

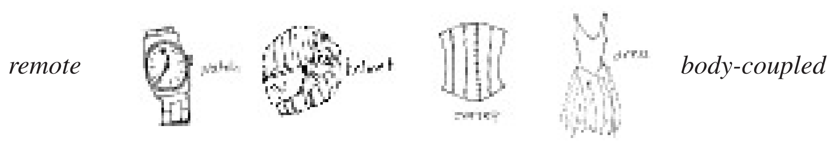
This axis refers to how much the wearer can transform or customize a garment. Although any article of clothing may ultimately be customized (e.g. altering its fit, tearing holes in the knees of jeans, attaching safety pins to leather jackets, wearing a shirt inside-out), the principle of mutability is intrinsic to certain garments. As mentioned in the



background section, Issey Miyake's APOC line allows individuals to cut their own clothing based on personal need or preference. Even more reconfigurable is a system of fabric and velcro squares that can be patched together to create surfaces and tubes for simple articles of clothing - pants, straight skirt, vest - and then separated and reassembled over and over again.

Off Body

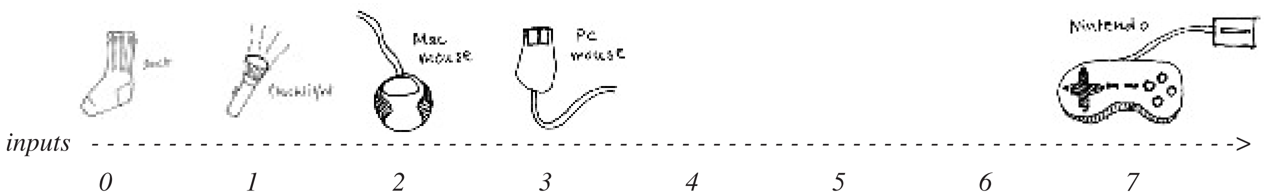
Unique to garments enhanced with technology, the principle of the remote body refers to the ability of a garment to detach itself from the wearer's body by responding to off-body (remote) stimuli, or by behaving independent from the wearer. Fabric garments are soft and pliant,



responding to body movements by stretching, bending, and billowing. A very rigid garment like a breastplate is indifferent to the body: it retains its shape regardless of who wears it or how the person moves, or even when it is empty. Because electronics allow input other than body movement, computational garments can be remote from the body without being rigid, and can respond to almost any input, whether physical (pressure) or intangible (web activity). For example, Maggie Orth's musical jacket plays music as keypads are depressed. Although interaction with the keypad is physical (finger pressure), the keypad is responsive to explicit manipulation rather than the natural motions and changes of the body. Technology can more closely couple clothing to the body as well. The MIT Media Lab, in collaboration with famous jeweler Harry Winston, designed a diamond-and-ruby brooch that pulses with light in time to a loved one's heartbeat, detected through embedded sensors. Other researchers are experimenting with fabrics that can change temperature or apply pressure to the body, based on body temperature or curvature.

Reactivity/Inputs

This axis charts how many stimuli a garment responds to. Any physical object is inherently responsive to ambient physical stimuli: wind, collision, gravity, wear and tear. However, electronics allow computational



garments to respond to any number of specific stimuli as well, physical or intangible, from motion (via accelerometers) to sound (via microphones) to transmitted digital data (via infrared or serial receivers). The number of inputs can range from zero (no explicit inputs; for example a wool sweater) to one (on/off; for example a light-up LED ring) to many.

Light/Luminosity

This axis refers to the modulation of light by or on a garment. Hoods and visors are examples of light blockage, providing shade to the face even in noontime sun. black clothing absorbs light. Sheer and transpar-

ent fabrics allow light to pass through the garment, perhaps illuminating the body beneath. Attraction to light seems to be a common human response; people of all cultures adorn themselves with beads, sequins, or mirrors that sparkle and catch or reflect light, acting as passive light displays. With technologies such as light bulbs, light-emitting diodes (LEDs), and electroluminescense (EL), active displays and the generation (rather than modulation) of light are possible.

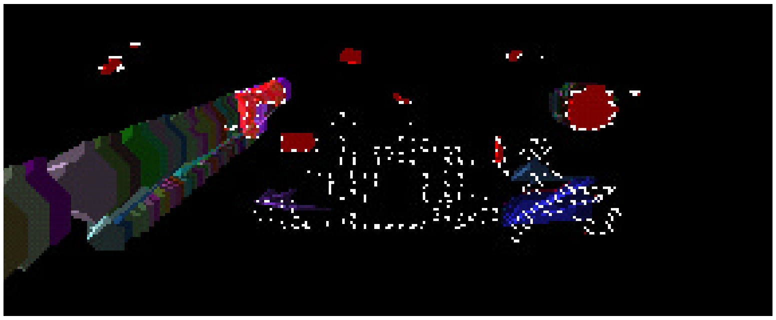
Hybrid Spaces

The identification of these design parameters, or axes, outlines a design space for computational clothing and provides a basis for more objective contextualization of a variety of garments. These axes also reflect the hybrid nature of computational fashion: while the parameters Ornamentation and Reactiviyt/Input are based on traditional fashion and computation, respectively, Remote Body is a theme uniquely pertinent to the synthesis of both areas. Thus the issues of a hybrid design field are not merely the sum of each parent, but also include specific axes that define a new design space.

The author, testing equipment configuration at a presentation of her work in Tokyo, March 2000.

Experiments

I explored computation and fashion by creating computational garments that experimented with the parameters outlined in the previous section: ornamentation, mobility, communication/identification, mutability, off-body responsiveness, and luminosity. This research has involved work in hardware and software as well as aesthetic form. All the prototype garments are facilitated through technology, but each explores a different aspect of expression or relationship to the body.



Silhouette

September - August 1998

Silhouette was a first attempt at using computation to augment the body's expressive capabilities. Body and garment shapes are used as input to a 3D graphics program. Video input from a camera is analyzed, its contours displayed and broken into closed shapes which solidify and float forward. As the video image shifts, a history of shapes builds in space. The shapes in turn create sound, with each shape generating a note based on its size (area).

Technical Methods

Silhouette was based on video input; the bulk of computation involved analyzing each frame of video, using 2D image processing techniques, in order to derive basic shape information for visualization. The techniques used were:

decolorizing - conversion of a color image into grayscale by averaging the red, green, and blue values

thresholding - conversion of grayscale into areas of black and white by selecting a "threshold" value; pixels below the threshold are set to 0 (black), pixels above set to 1 (white)

erosion - a technique for contracting solid forms; given a thresholded image, white forms are eroded by setting white edge pixels to black. edge pixels are white pixels adjacent to one or more black pixels.

outline - the subtraction of an eroded image from the original image; white pixels demarcate the edges of shapes in the original image.

The image processing techniques used in Silhouette create solid forms from the brighter areas in the video images. When the user wears white or reflective clothing, she can move her body and manipulate the garments to create abstract shapes and sound. Using the z-axis to represent the progression of time, the buildup of polygons creates a space of silhouette history. Quickly-changing shapes become islands in space and sprinklings of notes, while steady and constant shapes form extruded volumes and monotonic sound.

Image processing techniques, from top left: a grayscale image; thresholding; erosion; outline.
Facing page: Silhouette displays the outlined image of each frame of input video, and forms polygons from the closed shapes.

Precedents/Themes

The concept of being able to shift one's shape by manipulating garments on the body was inspired by Japanese Kabuki theater. Traditional Kabuki actors wear elaborate multilayered garments which can peeled away, retied, tucked and folded into new shapes while remaining onstage. This idea of metamorphosing origami-like garments prompted my interest in trying to find a way to visualize clothing shapes changing over time.

Design Space

Note: because Silhouette is not a garment, axes vary in relevance to the garment side of the project (input) versus the graphics visualization (output).

Ornamentation: Silhouette is fairly nonornamental; the choice and design of garments is based on light-reflectivity (for video input) and mutability of shape and form. The graphics end of the project, while aesthetically designed visually, is a visualization rather than a direct ornamentation of the body.

Practicality/Necessity: This project falls at the far end opposite Practicality; Silhouette provides information in terms of a history of garment shapes over time, but does so more for aesthetic reasons than for actual data production.

Storage/Mobility: Silhouette provides no storage, and is also very immobile; the required setup and orientation of video camera, pc, display, and baffling/light-blocking material renders this piece closer to a performance installation than a wearable garment.

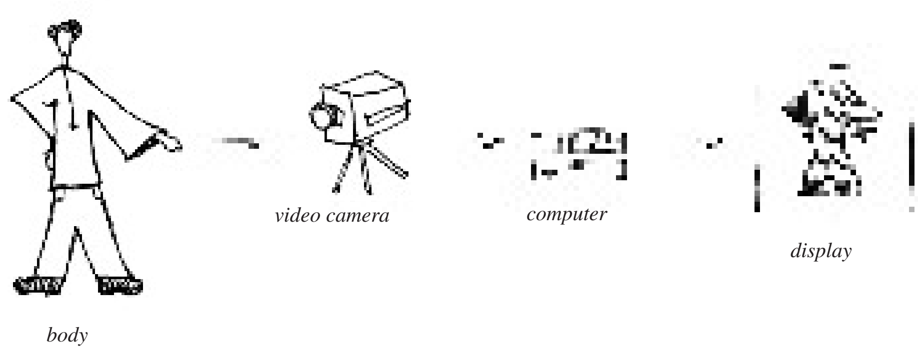
Communication/Identification: Silhouette is meant to play off of manipulations of garments in order to create varying shapes. The display of shape information might prompt the user to create shapes in response to onlookers, however this element is not inherent in the project. This would place the project perhaps slightly toward the communication end of the axis, but basically at the center/average.

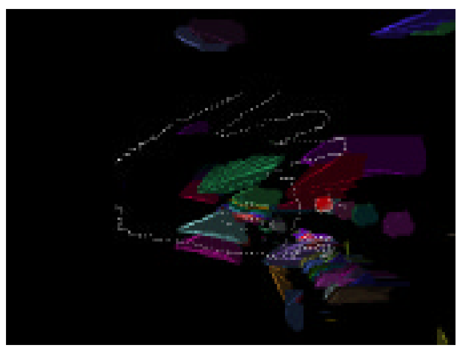
Mutability/Reconfigurability: The premise of this project is based on mutability of garment shape, orienting the garment side of the project at the mutable end of the axis. However, the piece taken as a combination of garment input and graphics visualization is fairly constant; although the input shape is changeable, the graphics and site of interaction are fixed.

Off Body: The graphics program does respond to video input which can include any object or light source, not only the body. However, Silhouette was intended to be based solely on the garment shapes, placing it at the opposite end from remote body.

Reactivity/Inputs: Although the video camera may pick up any number objects in the video frame, the video itself counts as only one input. Combined with on/off, Silhouette has two inputs.

Light/Luminosity: Light plays a large role in this project. The garments are designed to be highly light-reflective for ease of video pickup, placing them towards the luminous end of the axis (though not light-emitting).





Above: system diagram for Silhouette.
Left: using the hand as body input produces a variety of shapes: fingers, fingernails, highlights and inter-finger spaces.

Analysis

This project is closer to a performance piece or interactive installation that to a garment, because the program is so divorced from the body. Although intended to create sonified forms from the body, Silhouette does not differentiate between the shape of a sleeve and the highlighted edge of a monitor. As a result, specific garments must be worn, and a specific space set up (a black background or dropcloth to block light sources, other objects, etc.) in order for the piece to function as a body-shape-interpreting system. Even then, the distinction between solid and space is easily lost or reversed in the process of analysis. The polygonization method is quite rough, and edges of overlapping shapes are easily confused. In the open-house demonstrations, a retroreflective glove was used against a black background. While moving or waving the hand generated piecemeal shapes based on highlighted wrinkles in the fabric, closed shapes formed with the fingers (like the “ok” circle of thumb and forefinger) could be discerned fairly consistently. In this case, the piece was less of a body-silhouette-maker and more of a “bubble-blower.”

Overall, Silhouette was disappointing as an attempt to tie the body to computation in a compelling way. The piece lacked an inherent sensitivity to, or relationship with, the body; any video input could produce shapes and volumes. In addition, the effort to make garments suitable for being translated into shapes successfully involved using flat patches of retroreflective material on wrinkle-free black lycra, limiting the expressive design of the clothes themselves.

Silhouette helped me determine that the addition of a body to a computer program was not truly a fusion of fashion and computation, but an interaction between two separate parts. In order to explore a closer synthesis, I had to fuse the two haves into one: the computational garment. The following projects are my experiments in this field.

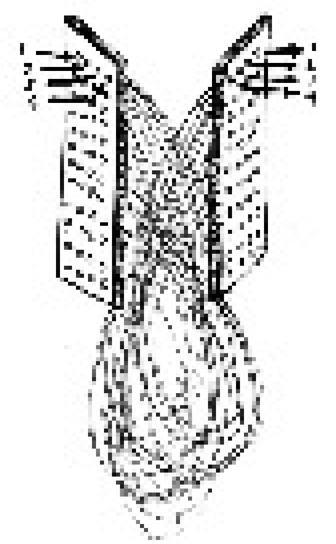
Perforation

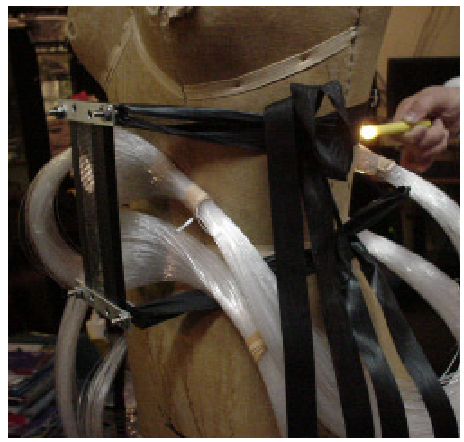
December 1998

In the fall of 1998, my colleague in the Aesthetics and Computation Group, Bill Keays, was working with optical fibers. He was experimenting with ways to use the fibers in conjunction with a computer monitor, placing one set of fiber ends against the monitor and channelling the image light to acrylic cubes. Formerly familiar with fiberoptics only through light-up flower arrangements and circus toys, I was captivated by the simple phenomenon embodied in this medium - of channeling light from one point in space to another.

An optical fiber is a long strand of transparent plastic (acrylic), coated externally with a transparent substance that has a different index of refraction from its acrylic core. Light entering the end of the fiber travels freely through the core, but bounces off the inside walls because of the difference in index of refraction. In effect, the light is trapped within the fiber until it exits the other end; the fiber is a path for the light, from one end, along its length, to the other end. Because of the fiber’s length and flexibility, the path can loop and curve in space and bend around solid objects.

Perforation uses optical fibers to circumvent the opacity of the human body. Several hundred lengths of optical fiber, threaded from a rectangular acrylic display panel at the front of the torso to matching points on the back, create a perforation in the body by passing light directly from front to back, and vice versa. The panels and fibers are held in place with ribbon laces at the sides of the body, tightened and tied





corset-fashion. Because the fiber ends are arranged in a dense grid of points, a coherent two-dimensional image of light is passed between the front and back of the body. A flashlight, laser pointer, or strong sunlight transmits visibly, and moving hand shadows work well as recognizable forms. I like the image of people shining flashlights back and forth through a slot in the torso.

Precedents/Themes

Transparency has a long history in fashion. Sheer hosiery, fishnet stockings, filmy organza dresses and peek-a-boo cutouts play with selective revealment using transparency. Transparency of the body itself is more the province of fantasy and science fiction; H.G.. Wells’s Invisible Man (1897), is a science fiction classic about a misanthropic genius who discovers a way to make himself invisible.

Design Space

Facing page, left: Perforation structure, with each optical fiber threaded between corresponding points on the front and back panels.
Right: Perforation transmits a coherent image of light and shadow; the beam of the flashlight appears as an illuminated circle on the front panel.

Ornamentation: Perforation lies towards the ornamental end of the axis, but not at the extremes; although the project is created to produce a specific visual effect, the purpose of the garment is more conceptual (void in the body) than purely ornamental.

Practicality/Necessity: This piece falls at the opposite end from protective/necessary, as it is not designed to provide any protection, covers little of the body (serves no preconceived utilitarian purpose), and is in fact somewhat unwieldy.

Storage/Mobility: No storage. However, all of Perforation's components are clearly visible and designed as part of the garment, pushing it towards the mobility end of the axis.

Communication/Identification: While Perforation is not necessarily a device for the wearer to communicate to others, it does invite interaction with and on the wearer's body, facilitating communication through the garment. This would place the piece towards the communication end of the axis, but not at the extreme.

Mutability/Reconfigurability: Perforation is at the opposite end from mutable/reconfigurable. Although the fiber end panels transmit dynamic, changeable light forms, the structure and setup of the piece are not changeable. In fact, Perforation must be worn in specific alignment and orientation in order for the illusion of the perforated body to ring true.

Off Body: On this axis, the piece lies midrange; Perforation responds to stimuli that originate off-body (from light sources, other people) but are directed at, and contextualized on, the body, i.e. the off-body sources of stimuli are aware of, and respond to, the wearer and his body.

Reactivity/Inputs: Technically the number of inputs of this piece are the number of fiber ends collecting light: 600 or so. However, because the meaningful data are actually the coherent 2D images formed by the collection of fibers, I would state the number of inputs as two: the light formation entering the front panel, and the one entering the back. Because Perforation is passive analog, there is no on/off distinction.

Also note that any number of people or light sources can affect each input.

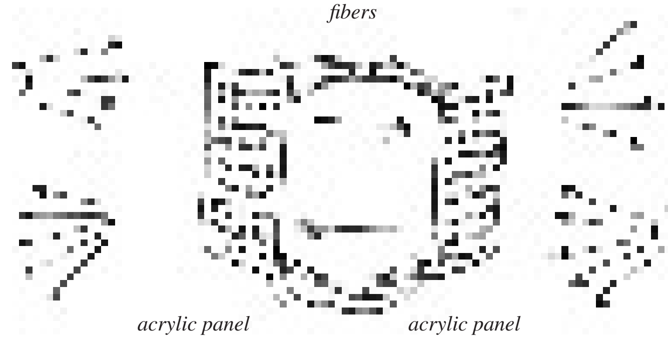
Light/Luminosity: Perforation, though passive, is oriented towards the transmission of direct emitted light (from flashlight, etc.). Taking this into account, the project falls past light-reflection towards the luminous end of the axis.

Analysis

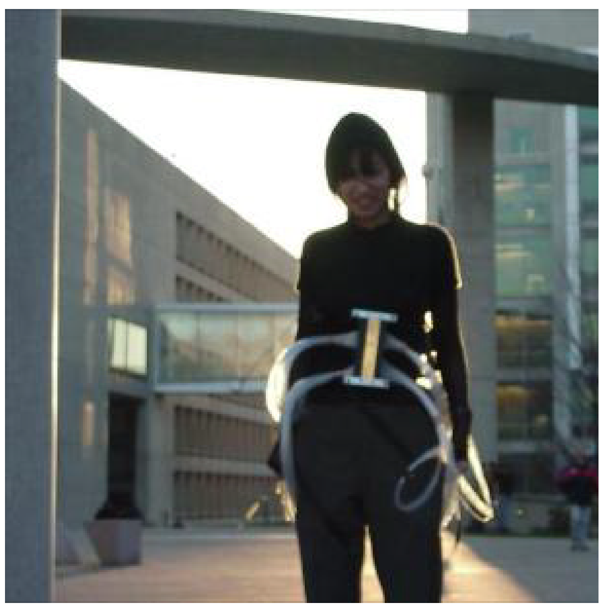
The impact of the piece relies on “truth of materials” - a configuration of fibers that readily reveals their optical properties, and the materiality of the fibers themselves - as much as on the startling illusion of a hole through the wearer’s flesh. Several people who saw the piece asked why I didn’t use two small video cameras and corresponding LCD panels, displaying the video from the front camera on the back LCD, and vice versa. The image would be higher-resolution and the arrangement would allow the transmission of detailed video images, not just ambient light hitting the panels. To me, the success of Perforation is very much intertwined with the fibers. The straightforward optical solution seems more true than an electronically processed signal elaboration of the concept -- the output light is the same as the input light, physically as well as perceptually. The fibers define the space of the garment, forming translucent draped curves around the body. In this sense, the fiber optics function simultaneously as technological elements, rerouting light, and as the garment’s primary formal element.

Perforation provokes us to think about our bodies in a different way. Ownership of the torso seems shared, as others can send signals or communicate through the fiberoptic patches. The body becomes a site of interaction. In fact the piece is at its most effective when light is being deliberately transmitted.

There is a paradox inherent in the idea of a “constructed void.” Perforation pursues a contradiction between the concept of void and its material manifestation in the piece.



System diagram for Perforation.



Outdoors, low-angled afternoon sunlight transmitted through the fibers from the back panel is strong enough to visibly illuminate the fron panel.

Garment Chimerical

January 1999 - May 1999

Following the construction of Perforation, I started to think more about the way that technology could change or create new relationships involving the body. In the case of Perforation, the relationship of the wearer to her body is changed by the existence of a transmitting medium in place of solid flesh, and other people relate to the wearer differently based on the fact that they can actively affect what is happening on the wearer's body. With the Garment Chimerical, I wanted to explore the element of fantasy, in how people conceive of themselves as fantastical beings, or even in how clothes themselves might dream of flying.

Technical

The use of sensors as a bridge tying the fantastical/imaginary to the physically real was my first step. The piece takes advantage of the malleability and dynamics of particular clothing details like zippers, snaps, controllable volume, and bendable joints, and uses them as the basis for clothing-based digital input. A Lego Dacta Control Lab acts as an analog-to-digital converter, providing a range of serial data to the graphics application based on several simple analog sensors incorporated into clothing:

rotational potentiometer - resistance varies with respect to rotation of small dial; when the dial and base are attached to separate braces, this becomes a hinge sensor that measures how open the hinge is. Inserted at the apex of a fabric insert, the sensor detects the lifting of the fabric.

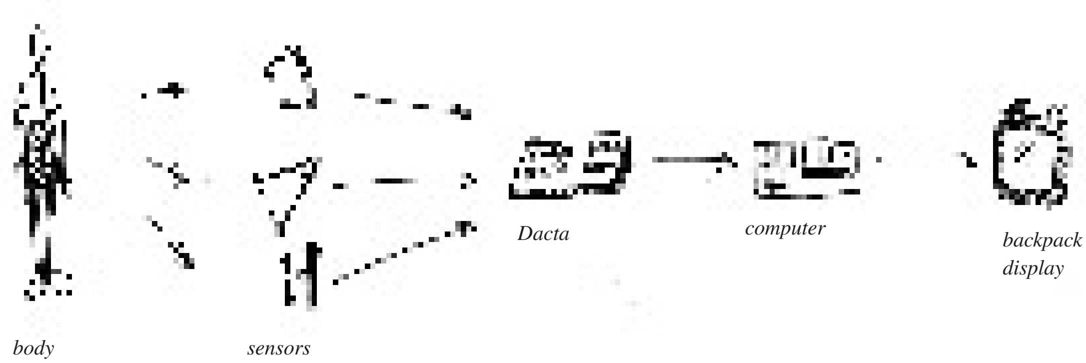
slide potentiometer - resistance varies with position of handle along straight bar; if attached to a zipper head, this measures how zipped or unzipped the zipper is.

metal contacts - a binary switch; resistance is zero when contacts are connected, infinite (maximum) when separate; can be used with closure elements such as snaps, hooks, etc.

bend sensor - a flexible strip whose resistance varies based on how much the strip is flexed; appropriate for measuring the body's bend in natural joints such as waist, elbow, or knee.

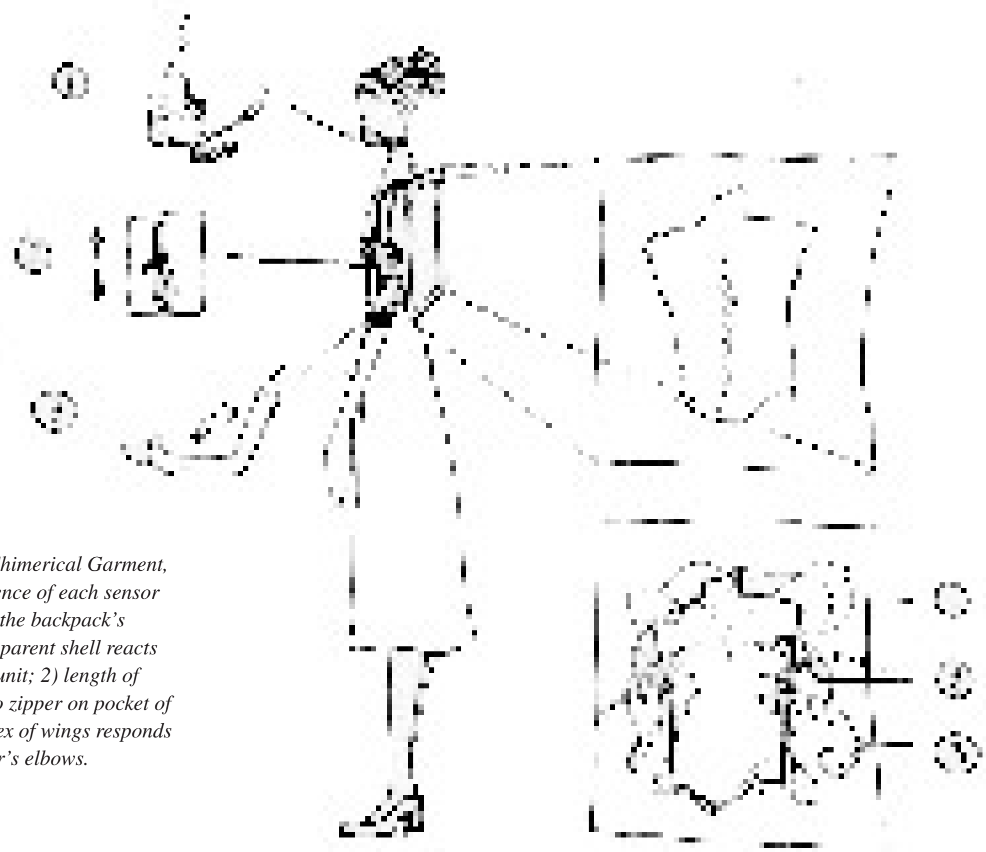
temperature sensor - resistance varies according to temperature of small ceramic element; when placed close to the mouth, this becomes a breath sensor as exhalation increases temperature.

Below, system diagram for Garment Chimerical.
Facing page, backpack LCD.



Sensor-imbedded clothing was prototyped on a jointed scale model human figure, and later implemented as an arm unit (zipper sensor, bend sensor) and chin unit (breath sensor).

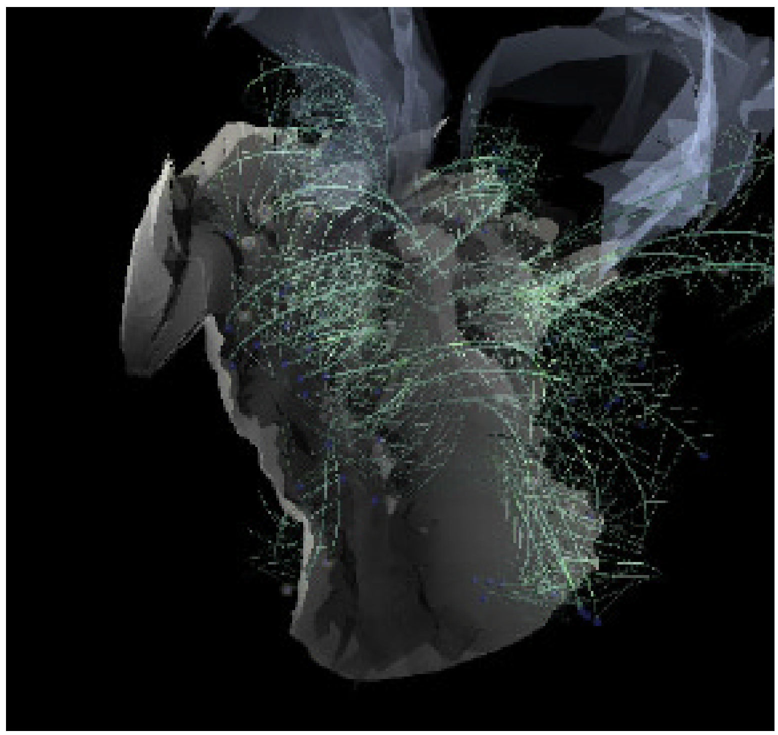
Originally I began working on an abstract graphic visualization that responded to the sensor data, and planned to project it on the body. But similarly to the Silhouette project (see above), the connection between this projected image and the wearer's body seemed too tenuous; even with the sensors as a direct body element, the piece seemed more like an installation than an article of clothing. Using a projection as the display fixed the piece's location in space, contrary to bodily mobility. In order to connect the graphics and the body more closely, I decided to place the display on the body. A flat Wacom LCD tablet (with Wacom pen-input disabled) is sewn into a custom-built backpack unit and worn on the back, displaying the 3D graphic application. With the



Reactivity diagram for Chimerical Garment, showing the correspondence of each sensor to a particular aspect of the backpack's virtual garment: 1) transparent shell reacts to breath sensor in chin unit; 2) length of wing tendrils responds to zipper on pocket of arm unit; 3) curvature/flex of wings responds to bend sensor at wearer's elbows.

graphics, I again decided to tie the virtual to the physical more closely by contextualizing the graphics themselves in relationship to the body. An abstracted 3D representation of a classical male back provides a virtual body space upon which to create the chimerical -- fantastical -- garment, a garment unbounded by physics, wearability, or feasibility.

The graphics are an embodiment of the wearer's imaginary clothing concepts; the prototype (theoretically the wearer would create her own virtual garment) consists of a transparent billowing skin, a more rigid shell, and delicate fern-like wings. The skin and shell are tied to the breath sensor, molding close to the back until exhalation causes them to gently expand (inflate). The wings blossom from the back when a pocket on the arm unit is unzipped, and flex with the bending of the wearer's arm.



Screenshot of 3D back and garment as they appear on the LCD.

Precedents/Themes

The back's relatively broad expanse lends itself well to being a site for display. The back is an ideal canvas for elaborate tattoos. Meanwhile, the backpack has in the last few decades evolved from military equipment to fashion accessory. Originally developed as a means to carry heavy and bulky equipment long distances, backpacks were adopted first by soldiers, then by hikers and outdoorsmen, and finally by students for carrying books. The assimilation of street and youth style by the fashion world included backpacks; in the mid-1990's, Prada designed a small black nylon backpack which became the status accessory *du jour*. Fashion designers' visions of millennial garb often include backpacks as part of the effort to gear themselves towards a mobile, fast-paced future.

Design Space

Ornamentation: This project falls high on the ornamentation axis, past Perforation. The piece is very much concerned with visual display, and constructing and projecting a desired image (the garment on the virtual back).

Practicality/Necessity: Chimerical Garment is far from necessary. It offers no protection or practical service.

Storage/Mobility: A small storage feature, in the form of pockets on the arm unit and the backpack strap, is provided. In terms of mobility, though, the PC, Dacta unit, and all power supplies are very heavy and bulky; in the original prototype the piece was tethered to a desktop PC and wall outlet (for power), rendering it immobile; in a later development, the requisite electronics were placed into a portable wheeled carrier and a large custom rechargeable battery was used for power, but the display and processing components remained heavy and cumbersome. Until power and processing become lighter and smaller, Chimerical Garment has very low mobility.

Communication/Identification: The piece is oriented near the extreme end of communicative/indentifying. The purpose of the project is to be able to display personal fantasies about self-image and fashion. The Chimerical Garment uses fantastical, imaginary clothing as an expression of identity, and instantiates them in order to show them to others.

Mutability/Reconfigurability: While the setup and physical structure of this project is basically fixed, the chimerical (virtual) garment that is displayed on the LCD is meant to be defined by the wearer. In this case,

the mutability of the pieces is dependent on the ability of the wearer to change the graphics program.

Off Body: The Chimerical Garment's "off body" factor is somewhat dependent on what "virtual garment" is programmed into the system, and how much it responds to the sensors. In general, the off body factor is fairly high, more so than Perforation's. The sensors do allow the garment to respond to physical movements and dynamics of the body. However, the display of the "virtual back" on the backpack LCD presents a body counterpart that is purely constructed and may have no relation to the wearer's body at all. Indeed, the classic male back is severely divorced from my own female, small back when I wear the garment for demo purposes. Despite the tie to the physical body through sensors, the chimerical garment instantiates a purely fantastical garment as well as a nonexistent - extremely remote - body.

Reactivity/Inputs: The piece has four degrees of freedom: each of the three sensors (breath, slide zipper, arm bend) and on/off.

Light/Luminosity: The LCD of the backpack is light-emitting (although this factor is not integral to the concept of the piece), placing Chimerical Garment near the extreme Luminous end of the axis.

Analysis

The Chimerical Garment enables the projection of imaginary clothing into the physical world. This piece was created as a prototype for garments that take account of unrealistic or impossible fantasies about our bodies and our selves as exotic, changeable creatures, and use these figments of imagination as expressive elements on the body. The emphasis on fantasy or the impossible and their role as a valid expression of identity through fashion is appealing to most people.

There were inevitably corporate sponsors who imagined dynamic logos, which I found disappointing, but which underlined the importance of distinguishing between developing technologies and developing concepts implemented through technology. Indeed, the technology used in the Chimerical Garment was often an issue. The 3D graphics hardware required to drive the application make it unacceptable to run the project with less than a desktop PC currently, because of performance. The LCD and Dacta Control Lab power specifications require a wall outlet or very large and heavy battery supply. These factors make the project seem more of a prototype than an actual wearable garment, although eventually the enabling technologies will be small and fast enough to make the piece truly mobile.

The sensors are simple and unsophisticated; most were obtained from Radio Shack. With the availability of higher-level physical information sensing devices, the Chimerical Garment could respond to heart rate, brain activity, perhaps even emotion. The responses of the virtual garment could be more sophisticated as well. In the current implementation, the mapping between sensor data and garment response is one-to-one: an increase in sensor value is reflected in an increasing length, volume, or curvature. The Chimerical Garment is successful as a base-level proposition for virtual+physical clothing. With higher-level input or output, the piece might begin to negotiate the relationship between body and virtual garment differently, for example behaving as an emotion indicator or "mood ring" cast, or letting physical movement gently influence, rather than dictate, the state of the virtual garment.

Above and facing page, the author wearing Chimerical Garment, including: arm unit, chin unit with breath sensor, and backpack LCD.

Halo

July 1999 - February 2000

As with Perforation, my exposure to interesting technologies through my colleagues at the Media Lab sparked the impulses for the project Halo. I was already eager to move past the bulky and tethered nature of the Chimerical Garment (tied to a PC or SGI), and wanted to create a self-contained, mobile and wearable garment. When Paul Yarin, a student from neighboring Tangible Media Group, lent me a swatch of electroluminescent (EL) material, I was drawn to the thin, flexible panel emitting a uniform blue-green light across its area. I conceived of using many panels to create a belt, using emergent-behavior concepts from computer science to create an autonomous dynamic pattern of light. I decided to build a system of small, fairly simple autonomous units that could communicate and interact with each other in order to create interesting light behaviors.

Halo is an example of a garment whose physical form is controlled by the wearer, but which evolves its own behavior. Halo is a configurable system of small glowing panels that connect together to form physical structures or surfaces on the body. Through embedded computation (Microchip PIC16F84 microcontrollers), each unit has its own flashing rhythm, and the ability to modify, assimilate, or transmit new rhythms. A unit transmits through the physical connections to its neighbors; thus the connection of multiple units creates both aesthetic form and computational structure. By taking one input rhythm and passing it from unit to unit, modifying it along the way, the garment evolves complex unscripted behavior based on initial simple data from the wearer (a direct recorded input rhythm, or rhythms automatically extracted from sensors on the body) or via IR from a PalmPilot device. Halo uses electroluminescent panels as the visual output and aesthetic element, and draws on established computer science concepts of cellular automata and emergent behavior to create a garment that blurs traditional fashion concepts of explicitly-controlled appearance, adherence to the body, and responsiveness.

Technical Architecture/System

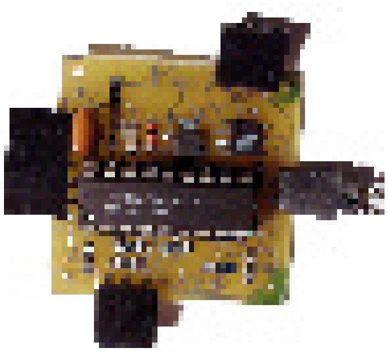
Unit

Unit circuitry is on 1.5”x1.5” printed circuit boards and using surface-mount components. An 18-pin DIP socket holds the PIC chip and allows it to be removed and replaced to facilitate programming.

Below: Halo unit circuit board with PIC, EL driver, and sockets for connectors. Lower right: circuit schematic. Facing page: Halo structure and Palm Pilot.

The brain of the Halo unit is the Microchip PIC16F84, a programmable microcontroller with 18 input/output pins, interrupt features, and internal counter. C code is compiled using MPLab software, and transferred to the PIC via a chip programmer connected serially to the PC.

Each Halo unit has its own output display, a single panel of electroluminescent (EL) material. An EL panel consists of a layer of phosphorescent material sandwiched between two flexible, conductive layers (one transparent). AC voltage applied across the conductive layers causes the phosphor to emit light.



An EL driver provides the high AC voltage needed for the EL to emit light. The driver has low power requirements, takes 4 - 5V DC and outputs 180 - 250 V AC.

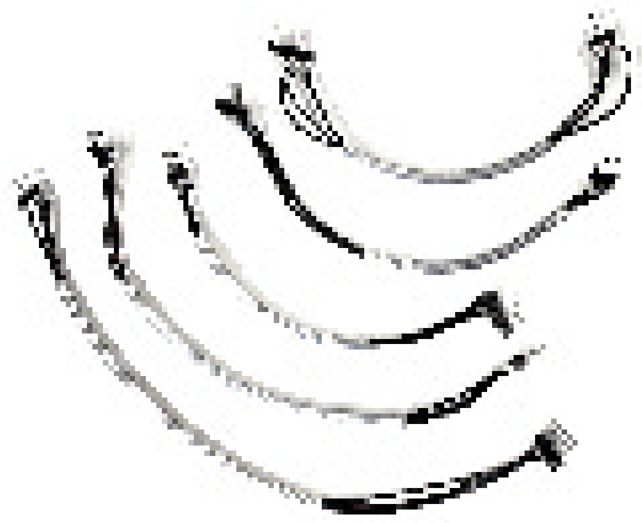
The program running on each PIC chip consists mainly of a rhythm interpreter and communication routines. Each Halo unit has one parent and up to two children, and communication flows from the first

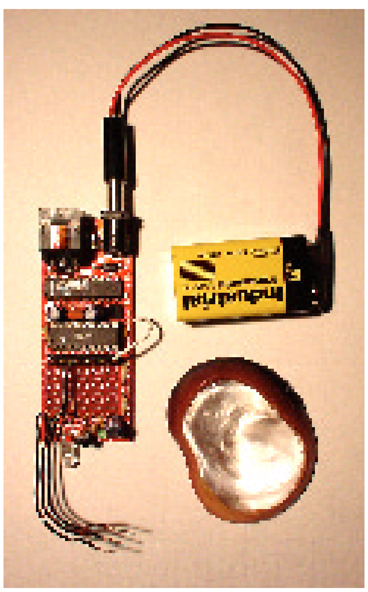
Connection of Halo units

("mama") unit through to the others based on the system's binary tree structure. Incoming messages are signalled by an interrupt routine that reads the new message and updates the rhythm buffer.

Connector

Communication is via RS232 over a single communication line in each connector. Connectors also carry power and ground lines, so that only one power supply (a 9V battery) drives the entire system. Long and short connectors are differentiated from each other electrically; rhythm modification based on connector type emphasizes the tie between physical construction of the garment, and informational/behavioral structure computationally.



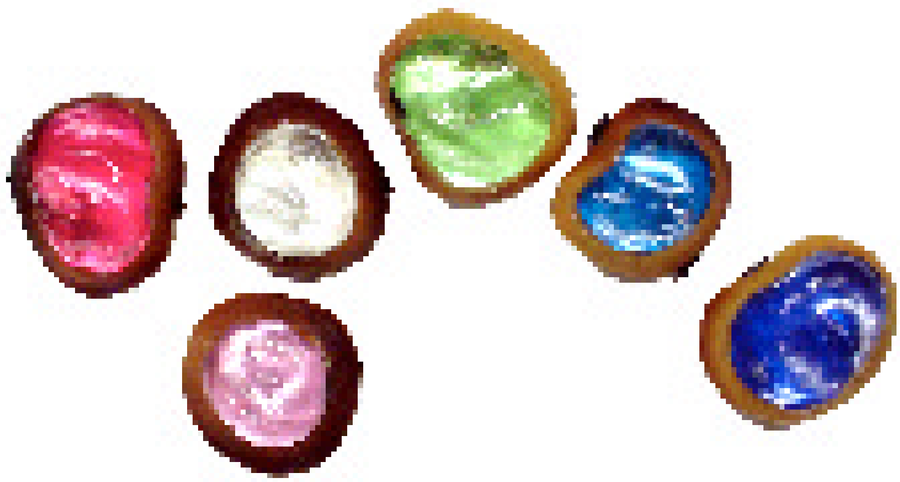


Mama

A single "mama" unit is the first parent and root of the tree structure for the system. The mama unit provides power to the entire system and handles rhythm input. When IR is detected through the IR receiver, the incoming message is checked for validity and then passed to the rest of the as a new rhythm.

Physical Design

More so than any of the other projects, Halo involved a great deal of physical design and fabrication. Part of the premise of my research is that technology can and should be incorporated into fashion with a sensitivity to traditional garment attributes: texture, appearance, wearability, etc. While positing this synthesis of form and behavior is easy, actually implementing a thoughtful design of physical form requires an entirely different set of skills and resources.



Above and facing page, the Halo system: Mama unit with IR receiver and battery power supply; multi-length connectors; Halo units.

Because technology is commonly associated with a specific "techno" or "cyberwear" look, I wanted to explore the insertion of technology into a more organic form. With each Halo panel conceived as a pebble-like jewel, I created molds for three different translucent pebble shapes: round, kidney, and lima bean. The original forms and the molds were created from polymer clay, a plastic substance which hardens at temperatures achievable in an ordinary oven. The actual pieces were cast in transparent resin.

To cover the edges of the units and provide space for the internal circuit boards, opaque bezels were created, also using the polymer clay. The polymer was allowed to brown in the oven, resulting in varying gradations of translucent brown harking back to tortoiseshell accessories popular in the 1950s.

Meanwhile, the connectors had to be designed for functionality, appearance, and especially durability, as they support the entire structure on the body. Sliding curved aluminum tubes house the connector wires, providing shape while allowing flexibility at joints so that the Halo panels hang and sway. This flexibility took its toll on the connector wires, which became brittle from the constant torsion and often broke. This was remedied by using transparent shrink tubing to reinforce the flexing joints, distributing bend pressure along a length of the wire instead of at a single point.

The physical design of the Halo units was integral to the piece as a whole; the actual fabrication of the components was time consuming, though, and difficult to accomplish on my own without more powerful fabrication resources at my disposal. The handmade nature of the units is evident in the finished piece. While not necessarily a drawback, the Halo form factor does lack the high level of "finish" apparent in professionally-manufactured objects. These issues of design and implementation, who performs them and to what extent, will be discussed further in the Conclusions section.

Precedents/Themes

Halo has precedents in many waist-situated accessories. Jewelled belts, medieval pendant belts (with suspended panels and swags), and Halston's sterling silver bean-shaped hip-pendants of the 1970s are all adornments of the waist. The peplum, a gathered and flared insert at the hips, was popular in the 1950's as an offset to the slim pencil skirts in style.

Several modular systems of individual units have been created at the lab; I was especially interested in Triangles (Maggie Orth and Matt Gorbet), Tiles (Kwin Kramer), and Nami (Rob Poor). These projects all provide reconfigurable physical systems linked to computation, but vary in computational structure. I looked at these systems as a basis for deciding on models of control (centralized versus distributed), communication (common bus versus direct neighbor-to-neighbor messaging), and mobile code.

Behaviorally, Halo parallels the effect of water trickling through pebbles. As the water flows, each pebble perturbs the current, creating a more complex dynamic. Similarly, Halo's input rhythms flows through the physical structure of Halo units, with each unit modifying the rhythm until a differentiated set of rhythms results.

Design Space

Ornamentation: Halo is almost purely ornamental; like Chimerical Garment, the piece falls past Perforation towards the ornamental end of the axis.

Practicality/Necessity: At the extreme opposite end from protective, Halo provides no protection and has little practical value.

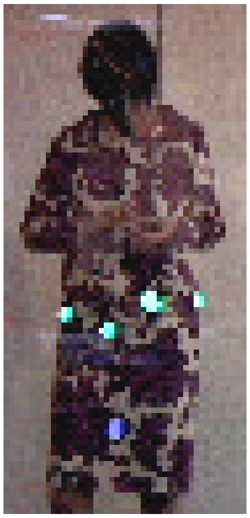
Storage/Mobility: No storage. All power, processing, etc. is designed to be light, small and wearable, making Halo highly mobile.

Communication/Identification: Halo allows the wearer to input new rhythms to the system; choice of rhythms is a manner of personal choice reflected in the behavior of the garment. Like Perforation, though, Halo also allows for others to communicate to the wearer, by accepting rhythm inputs from other people's Palm Pilot via IR. The transmitted data is not as informationally meaningful as a conversation or text message would be, but is explicit communication from another person.

Mutability/Reconfigurability: Halo's unit-and-connector system is specifically designed to be reconfigurable. Structures can be built, taken apart, and rebuilt repeatedly. This provides mutability at the physical/form level; at the computational level, the PIC chips must be re-burned in order to modify code. Some sort of rhythm-modification programmability via an external unit, as mentioned earlier, would make computational mutability easier and more of an accessible feature. Behaviorally, Halo's rhythm patterns are based on (but not scripted by) input rhythms, allowing the wearer influence rather than complete control over the piece's behavior as a whole.

Off Body: Halo's flexible connectors and web-like structure result in a pliant garment that must be supported on the body and which sways with the wearer's movements. However, Halos responds to rhythm inputs explicitly created by the wearer or others, which are most likely unrelated to the body. The wireless infrared communication capability divorces stimuli from the body as well.

Reactivity/Inputs: Halo has 3 inputs: physical configuration, input rhythm, and on/off.





Light/Luminosity: Halo's rhythms are based on light emission, placing the project at the extreme Luminous end of the spectrum.

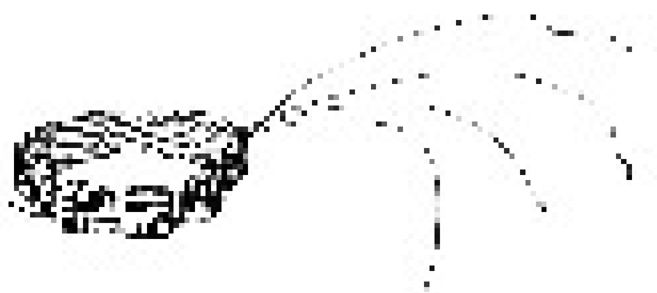
Analysis

Facing page, top to bottom: stills from video showing Halo worn and activated; creating an input rhythm on the Palm Pilot; sketches of ways the Halo units could be configured on the body.

Halo is an integration of software, hardware, and physical form, and an attempt to devise a new garment type. The modular nature of the units and connectors, and the communication model and rhythm flow structure, enable a strong relationship between physical configuration and computational behavior. Halo introduces the notion of influence instead of direct control; rather than scripting or orchestrating the behavior of the system, the wearer provides a seed input that evolves into a more complex behavior. Thus Halo arrives at a behavior based on several factors: configuration of tree structure; use of varying length connectors; and external input rhythm. Because new rhythms are sent via IR using a standard protocol, input source is not limited to the wearer, but might come from the Palm Pilot of a stranger across the room or even another person's Halo. In this sense, Halo defines a new garment paradigm: the (computational) multi-person garment.

Halo was designed as it was built, and this cumulative approach is evident in several aspects of the project. Most notably, the rhythm representation makes generalized and interesting rhythm modification very awkward. Because rhythms are represented as series of instructions, very few generalizations or assumptions can be made and used as a basis for rhythm modification unless hard coded. The current implementation of Halo assumes a monotonic rhythm, with one "on" period and one "off" period looped continuously. Rhythm modifications consist of varying the lengths of the on or off periods -- sufficient, but basic. This rhythm-interpreter model was adopted to allow for rhythms dependent on other data, such as sensor values or internal state. The sensors were never implemented as focus shifted to modifying rhythms computationally rather than through dependencies, but the vestiges of that earlier idea remain. A more appropriate model for rhythms would be to encode rhythms as series of on or off bits, with each bit representing a set interval of time (for example, 0.1 second). Complex rhythms could be encoded, and could be more easily modified by toggling, shifting, copying, etc. the bits.

As a reconfigurable system, Halo works quite well physically but is not so malleable computationally. Rhythm input and physical reconfiguration are the only ways to change the behavior of the garment. Rhythm-modification rules are hard coded onto the PIC chip, so the chip must be taken out, programmed, and replaced in order to modify the rhythm filter. Similarly, the starting-state rhythm of each unit is hard coded; there is no way to directly program the rhythm of a specific unit. The ability to program these aspects of the unit without removing the chip would greatly increase the flexibility of the piece. This might be done by building knowledge of the system's structure at some point, and being able to address specific units. It could also be done by providing each unit with a "programming port" to receive new program input from an external device such as the Palm Pilot.



Hula Hoop

March - April 2000

Hula Hoop is a conceptual sketch for a multiple-body garment based on accidental contact with others. Each Hula Hoop acts as a charm bracelet, with small LED panels recording the patterns of brief contact with other Hula Hoops. Long slender "feelers" extend from the bracelet; when they come into contact with another unit's feelers, the voltage changes are recorded and used to form a noise pattern on one of the LED matrix panels, instantiating a new "charm". The collection of noise patterns create a set of charms that might slide and move along the bracelet's length like beads on a wire. The notion of transference through unintentional physical contact is the basis for this project.

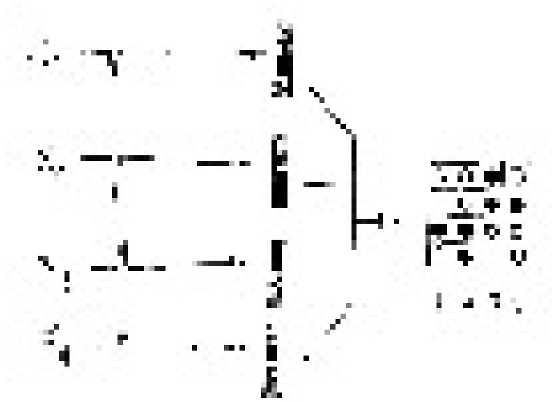
Technical

Unlike Halo, Hula Hoop relies on centralized control. A single PIC chip handles feeler input and also updates the illumination of the LED matrix displays. Contact data is stored internally and used to determine the state of the LED matrices each clock cycle.

Feelers

Four feelers extend from each Hula Hoop bracelet, facilitating physical contact with another unit without explicitly "docking" to the other device. The feelers themselves are long wires extending from internal circuitry on the bracelet. The point of connection on the circuit is polled each clock cycle by the PIC. When feelers make contact, noise in the circuit is read as a differential value, for example a 0.5V decrease in voltage.

LED matrices
The differential values provided by the feelers is translated into a visual pattern for display on the LED matrices. This translation could occur any number of ways. In the simple example below, differential values are rounded to one of four threshold values, and displayed as bar chart-like columns. Data from four feelers creates a pattern for a four by four LED matrix.



Precedents/Themes

The idea of communicating with or collecting data from neighbors is embodied by many precedents. The aforementioned MEME tags from the MIT Media Lab trade information about their wearers, even without an explicit “send data” instruction from the wearer. Similarly, Philips Design’s Hot Badges broadcast information about the wearer’s tastes and look for badges with similar data. While these systems involve communication through broadcasting and proximity, though, Hula Hoop attempts to use inadvertent physical contact as a form of data collection or communication.

An apt metaphor for this project is the transferring of colored lint as two people brush against each other. As one moves through a crowd, bits of lint record points of contact and perhaps garment colors of the people passed throughout the day. Although a noisy form of data collection, the specks of color that might appear form a record of momentary contacts and passages.

Design Space

Ornamentation: Hula Hoop is relatively high on the ornamentation axis., although not at the extremes with Halo and Chimerical Garment. The main purpose of Hula Hoop is to build a cumulative abstract record of accidental contacts.

Practicality/Necessity: This project has very little utilitarian purpose.

Storage/Mobility: Although providing no storage, Hula Hoop is designed to be highly mobile, with display bracelet, power and computation all lightweight and residing on the body.

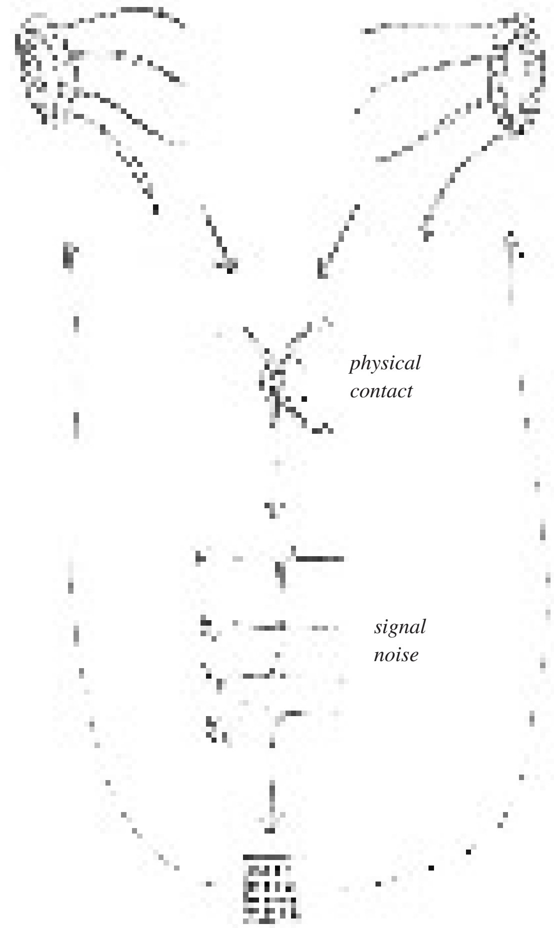
Communication/Identification: Hula Hoop falls far towards the communication end of this axis. Although implicit (through accidental contact), the project's abstract patterns are based on brief moments of exchange with another person. At the same time, the inherent noisiness of the data prevents concrete retrieval of specific contact information.

Mutability/Reconfigurability: Hula Hoop is not reconfigurable. LED patterns are based on contact, not on direct user input, and the piece must be worn at a specific orientation such that the feelers extend into space, allowing contact with other units.

Off Body: Hula Hoop lies toward the off-body responsive end of this axis. Input is based on physical contact with other units, which is partly based on body orientation and position. However, because the intention is for contact to be accidental, not directed, the collision of bodies is assumed to be fairly random rather than based on specific body position.

Reactivity/Input: Hula Hoop's number of inputs is one (on/off) plus the number of feelers (four).

Light/Luminosity: The output/display device for this project is LED matrices, which emit light. This places Hula Hoop at the luminescent end of the axis.



System diagram for Hula Hoop.

Analysis

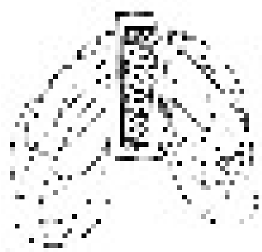
Hula Hoop builds off of the multiple-body, or societal, garment paradigm introduced with the Palm Pilot input aspect of Halo. A single Hula Hoop unit is meaningless because the nature of the garment is to make contact with others. This direction is particularly suited to, and can only really be enabled by, computation and technology. In this respect, Hula Hoop is a "next step" project concept that begins to specifically address the notion of garment-to-garment interactions.

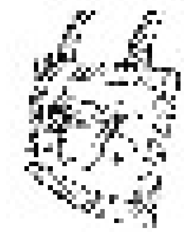
Data noise is a major issue of this project. On the one hand, an exploration of noise as an abstract information set is an interesting notion. However, the line between "noise" and "noisy data" is especially tenuous for Hula Hoop. Contact data is based on differences in current or voltage when two feelers brush against each other, connecting the internal bracelet circuits. But such electric changes are apt to happen all the time, as the feelers are basically exposed wires vulnerable to any charge. The problem is that some exchange or generation of data must occur from physical contact between two Hula Hoops. But the stipulation that the contact be unintentional, following the lint metaphor, means that the data-generating opportunity lasts only a moment. This struggle to implement a very precise concept sets Hula Hoop slightly apart from the previous experiments, which tended to be inspired and driven by an interest in particular technologies as well as a more abstract concept.

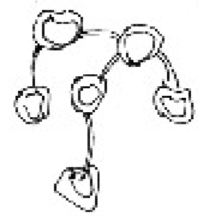
Analysis

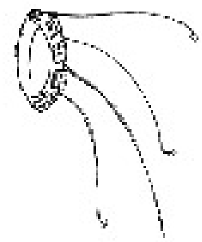
Looking at the body of this thesis work as a whole has helped me to identify and populate the axes of the computational fashion design space, and has also raised issues about the process of creating within this field.


Silhouette


Perforation


Garment Chimerical


Halo


Hula Hoop

Evaluation

This research was continually evaluated through weekly critique sessions with my peers in the Aesthetics and Computation Group at the MIT Media Lab, feedback from my readers on periodical updates on work as it progressed, and informal presentations and discussion with visitors.

There are no set formulae for calculating the success of this work in absolute terms. Fashion is a notoriously mercurial field; fads ignite and quickly die, to resurface years later or never again. As an aesthetic form, fashion is oriented towards style and adornment as an expression of the individual self. Hence fashion is characterized by individual choice, and a garment cannot really be categorized finally as good or bad. As a basis for more objective evaluation I present the body of work as a survey of conceptual possibilities, and consider the following:

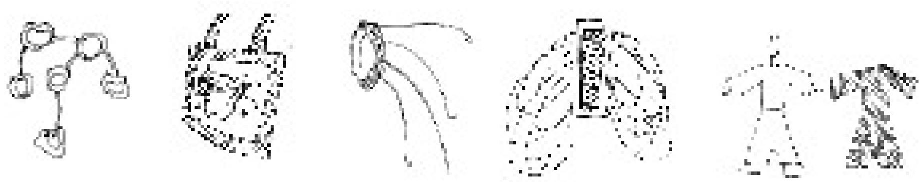
- Have I identified and addressed a sufficient breadth of themes in fashion and technology?
- Does my work have a distinct relevance to the body, fashion and expression?
- Are my explorations conceptually provocative/effective?

Design Space

While the five research experiments presented in this thesis differ widely in their conceptual foundations, they can be related to one another based on the design principles outlined earlier. In this section, the projects are sorted along each axis. As mentioned in the Design Space section, each axis represents a linear space within which garments can be placed. The positioning of a specific garment is somewhat subjective, but provides a more objective basis for comparing aspects of different garments.

Ornamentation
All five projects are fairly ornamental, and occupy a very narrow range of the ornamentation spectrum. They are sorted based on how much their physical forms and appearances were explicitly designed. A major portion of Halo's design went into the design and fabrication of the unit shells, whereas Silhouette's garments were created based on mutability of shape and light reflectivity, not aesthetics.

ornamental



nonornamental

Practicality/Necessity
None of the experiments has a high utilitarian value, as they were designed with conceptual issues in mind more than practically. Even within the narrower scope of nonpractical pieces, though, the projects

practical

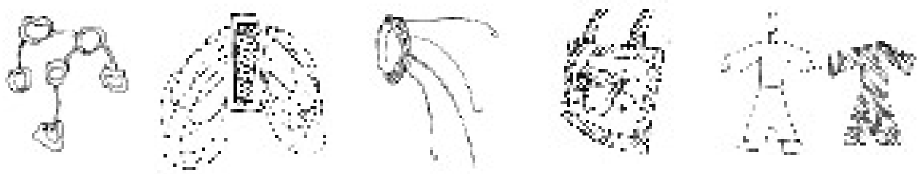
nonutilitarian

can be differentiated based on the idea of information generation, storage, or retrieval as a potentially useful or practical attribute. Thus Silhouette might be regarded as providing a history of precise shape data. Hula Hoop also records data based on momentary contacts, but because the data is so inherently noisy, it is useful only for its abstract nature and not as a consistent record of values. Chimerical Garment is not a data record but is a tool for displaying imaginary garments. Halo and Perforation, meanwhile, are based solely on concepts of the body and control.

Storage/Mobility

The projects fall along a wider range of the mobility axis, with Halo, Perforation, and Hula Hoop fabricated such that they are self-contained,

capacious/ mobile



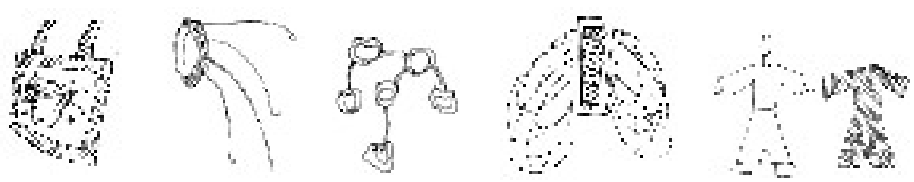
storageless/ encumbering

light and wearable. Garment Chimerical was envisioned as being similarly wearable and was eventually encapsulated into a portable configuration, but the hardware and power supplies are very heavy and bulky relative to the other projects. Silhouette is not a garment at all, but more of an interactive installation or performance piece.

Communication/Identification

All of the projects involve a display or output device of some sort, and display or transmission is inherently a form of communication. Garments were situated on this axis based on how much the display is

meaningful/ transmitting



impartial/ mute

controlled by the user, or on explicit exchange of information between multiple people. Because Chimerical Garment is specifically designed to communicate figments of the wearer's imagination, it is considered the most communicative. Hula Hoop, Halo and Perforation all provide for exchange of input between the wearer and others, while Silhouette is much more indirectly based on the wearer.

Mutability/Reconfigurability

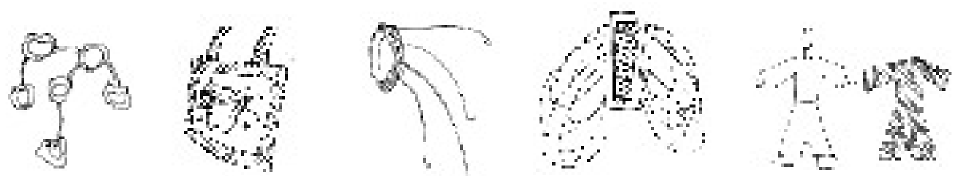
The experiments vary widely in reconfigurability. Halo is physically as well as behaviorally reconfigurable; Garment Chimerical is fixed in

mutable  *fixed*

terms of physical configuration but highly customizable (and meant to be customized) in terms of the virtual garment displayed on the backpack. Silhouette, Hula Hoop and Perforation are all fixed in terms of their orientation on or to the body.

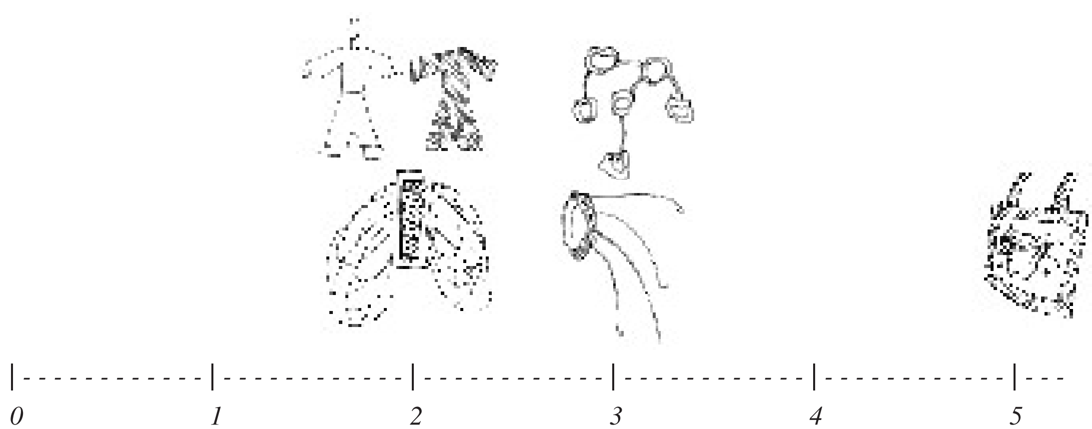
Off Body

Placement on this axis is based on the number of inputs that come from physically remote sources, e.g. another person. Although Garment Chimerical responds to sensors on the wearer's body, the creation of an entirely remote/virtual space with an alternate back places it further towards the remote end of the axis.

remote  *body-coupled*

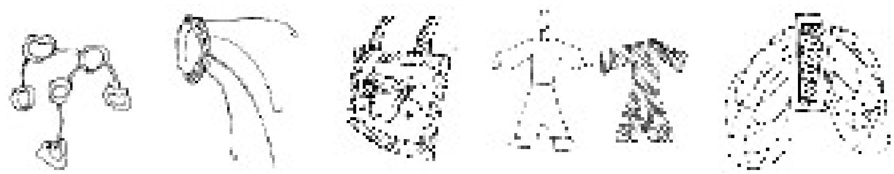
Reactivity/Inputs

This is the only axis with fixed, discrete values.

inputs 

Light/Luminosity

Luminosity is a common factor in all five projects. Halo and Hula Hoop both incorporate light-emitting technologies for the aesthetic impact of glowing devices, while in Silhouette and Garment Chimerical, the luminosity is a by-product of a higher-level display device (monitor and LCD, respectively). Perforation is passive, manipulating existing light rather generating its own.

light-emitting  *light-shielding*

Patterns in the Design Space?

There do not seem to be many discernible patterns in the design space of these five projects. All five pieces are highly ornamental as well as nonutilitarian, a common relationship noted in the introduction to the design space. Indeed, much of this research work has intentionally been directed away from the more practical realm of wearable computing in the cyborg sense (see background section), and towards concepts that involve self-expression, the body and control. It is interesting to note that the ordering of the experiments based on Communication/ Identification is the exact reverse of the Reactiviy/Inputs ordering. It does make sense that higher-level communication or expression might require a greater number of controlling parameters, or conversely that a system with more inputs would behave in a more complex manner. Nevertheless, I think that because the axes themselves were distilled as separate fundamental themes of computational fashion, dependencies among the various parameters are ideally minimal.

Body Relationships

Often in my explanation of this research to colleagues, sponsors, etc. I talk about the idea of exploring and expanding body relationships using technology and computation. Originally this was a way to posit my work not as solely ornamental or visual (as fashion is frequently regarded as), but also involving concepts of the body, self, and the people and space around us. In attempting to qualify my own vague claims, I have looked at each project in terms of explicit relationships addressed or enhanced by technology:

Silhouette - body (hand) to space (projection area or display); physical to abstract.

Perforation - body to self; others to body (body as site of interaction, communication of/with others through/on body); body to environment (sunlight passing through, tree shadows).

Garment Chimerical - body to fantasy; body to others; personal fantasy to others.

Halo - body to computation and structure (configuration/construction of garment from halo units); garment as entity (garment to self?); others to body (PalmPilot IR rhythms); body to garment (input from self, from sensors); garment to garment (auto IR rhythm).

Hula Hoop - garment to garment (exchange of charms); body to garment (hula hoop action).

Garment Paradigms

Conceptually, this work mediates relationships between the body, appearance, personality and environment in new ways by programming garment behaviors outside the realm of conventional fashion. The ability to generate behaviors through computation leads to a few new paradigms for garment functionality.

Just as Chimerical Garment presents physically-controlled manipulation of computational form, there could also be the prospect of computationally-controlled manipulation of physical form. Traditional clothing incorporates motion in many ways: garments move with the body; fabric drapes and folds based on its fiber, weave and orientation; the cut of a garment can be stiff, pliable, fitted, flowing. Clothes move in response to direct physical forces: a breeze, the pressure of a body, gravity, static. Through computation, clothes can move in response to anything, physical or not: sound, web activity, light, memory. It would be interesting to see how different types of responsiveness might change the way we feel connected to our bodies and to the things around us.

Halo portends a new garment paradigm, that of societal fashion, or multiple-body garments. Carrying the previous concept of responsiveness further, computational garments can respond to each other. They may generate data for use by other garments of the same type, or they might explicitly exchange elements or transmit messages. As fireflies swarm together, they begin to synchronize their flashing patterns. Similar collective behaviors in clothing could generate or identify spontaneous societies of people. Playing upon the fashion industry's dynamic between imitation and distinction, behaviors could converge or diverge to promote the community or the individual. As personal commodities with differentiable behaviors, garments could become collections or representations of people, to be traded or dispersed. In this respect, the role of fashion as a way of expressing oneself to, or sharing oneself with, the outside world could be enhanced and drastically transformed.

Conclusions

The Role of Technology and Computation in Fashion

Technology as Fashion Element
A note here: my goal has not been to develop new hardware technology, but rather to draw on the vast pool of existing resources and present electronic technologies as expressive, aesthetic clothing elements. Many technologies lend themselves well to fashion. These include the devices used in this research (microprocessors, sensors, EL, LEDs, optical fiber) as well many others yet to be explored in the context of fashion: muscle wire, a type of metal alloy that shifts between physical form states according to heat, and organic light-emitting displays (OLEDs), which are flexible and addressable light output devices that can be applied to non-planar surfaces.

Computation as an Expressive Component of Fashion
The creation of expressive components through computation; the ways that elements such as audio rhythm, physical movement, visual texture and pattern can be computationally created and then incorporated into garments as factors of immediate personal surrounding.

System Architectures

The design of hardware and software to support individual garment projects was a large part of this thesis work. For me, each project was a combination hardware/software/physical task. The exploratory process of conceiving ideas and then implementing them, learning new techniques as necessary (e.g. PIC programming, printed circuit board layout, electronic circuitry) resulted in custom architectures for each project. In hindsight, though, many aspects common to several projects could have been generalized into modular components.
For instance, I implemented the Chimerical Garment using the LEGO Dacta as the input system, with very simple analog sensors. After gaining experience with more complicated circuitry and PIC microprocessor programming while working on Halo, I could have used a single PIC instead of the Dacta, making the Chimerical Garment far more mobile and able to utilize more elaborate sensors (digital accelerometers, for example).

Indeed, the PIC for me emerged as the single most versatile component among the various technologies I was exposed to in my research. In combination with various sensors and connectors, and reusable code for serial communication, the PIC provides a generic yet powerful computational platform for building technological garments.

In terms of a general system architecture, Halo utilizes a fairly modular structure that could be modified for a variety of other projects. The boards are minimalistic, consisting basically of the PIC, accessible lines to the microprocessor's input and output lines (in Halo's case, via connector sockets), and the driver for the output display (electroluminescent panel driving IC). The most frustrating factor in implementing Halo was not designing the circuits or writing the software, but actually assembling the physical circuit boards, connectors and forms: soldering, wiring, etc. Thus a key feature of any generalized system is physical modularity.

At the MIT Media Lab, the Crickets project is a generalized modular system for building and programming robots and toys. Standardized sockets and connectors facilitate the addition or replacement of sensors and motors, and microprocessor-enclosing "programmable bricks" provide computational control and mediation of the peripheral devices.

In a similar vein, a standard system for computational fashion would include PIC-driven base units that could be amplified with modular input (sensors, serial connectors) and output (LCD, EL, LED) devices. Small sockets would facilitate the swapping in and out of peripheral devices, with socket bases available for custom connection to anything else. A basic software level might include normalization of input sensor values for interchangeability, standard code for driving output displays, and serial communication code.

Unlike Crickets, whose goal is to create behaviors, computational garments are based equally on behavior and aesthetic. There is no system that generalizes the creation of texture, visual beauty, and body. In addition, the strength of computational fashion is derived from concepts and relationships enhanced or made concrete through technology and designed for the body; neither the concepts nor the physical designs can be limited to combinations of discrete units.

Process

The process for creating these projects was a combination of conceptualization, learning the necessary skills for implementation, hardware and software design, form design, and fabrication. A wide range of techniques was employed in order to create working prototypes: circuit design, programming, molding and casting, sculpting, sewing, and soldering. One of the major questions I faced throughout my experiments was: Why am I doing everything myself? With an abundance of electrical engineers, UROPs and computer scientists at MIT, what is the value of implementing concepts on my own rather than delegating tasks to "specialist" collaborators?

When I began developing an interest in fashion, I was awed by fashion designers' ability to imagine beautiful clothes and make them real, actually fitting the body. Later I discovered that fashion designers produce only sketches of clothing, which are passed to cutters for actual translation into fabric. This was a bitter disappointment; to me, cutting the patterns seemed as much an art as designing the sketches. The truth is, though, that every fashion designer is familiar with the entire process of creating a garment, from sketch to pattern to stitch. Beautiful clothes cannot be designed without knowledge of materiality. The best designers are those with the greatest understanding of fabric and cut, resulting in clothes that are beautifully shaped and constructed.

Similarly, I think the value of designing all aspects of computational fashion oneself is in a deeper knowledge and familiarity with the media (computation, technology, materiality). Often, inspiration and innovation come from the medium: the tortoiseshell effect of burning polymer clay, for example, or the notion of flashing light rhythms derived from an interest in EL. Certainly the experience of soldering hundreds of millimeter-long surface-mount components by hand affords a unique perspective on reasonable placement schemes and board density. At some level, though, the value of doing rote assembly tasks – gluing, soldering, wire stripping – becomes trivial in comparison to the importance of actually designing. The limitations of one's own skills, time and resources can also be limitations on the quality of the finished piece. Consistently perfect seams, regular surfaces, and invisible adhesion are almost impossible to achieve by hand.

Given the advantages of designing on all levels, the actual process of doing so is difficult. The value of combining engineering and aesthetics lies in the symbiosis of the two fields resulting in new models, paradigms, and concepts. Yet while concepts might be envisioned in tandem, implementation by one person is a serial process. When working on Halo, for instance, I found myself switching focus between the form factor, hardware and software issues. While working on software, my design of the system was influenced by interesting software ideas - mobile code, rhythm malleability - without necessarily contextualizing behaviors with respect to the body. On the other hand, when I was focused on designing the physical form I sometimes lost sight of electrical issues such as protecting the circuit from shorting out. The mediation between the different aspects of the field – hardware, software, form – while maintaining a vision of the system as a whole, is crucial in developing a well-integrated finished product. I think this mediation, the ability to work in multiple areas simultaneously, is itself a skill, one which hopefully develops out of experience.

The Future: Mass and Synthesis

With this research work I have tried to explore the ways that technology and computation can expand the vocabulary of fashion and change the way we think about our bodies as they relate to others and the environment. From the experience of designing and implementing each project, it is clear that we must somehow become more facile, able to move dexterously between various aspects of design. Beyond a generalized system for creating computational garments lies the fundamental need to change our notions of hardware and software as separate entities, removed from the physicality of fabric, wind and shape.

In architecture, the physicality and size of the medium necessitates an ability to think in terms of both structure and space, engineering and aesthetics. Architecture itself cannot be defined as a purely artistic field, nor as solely a science. In a similar vein, computational fashion is a synthesis of aesthetics and engineering. Fashion design, electronic design and computer programming are such established fields on their own that developing a design methodology to incorporate all three is difficult. Hopefully as we explore further, patterns in design and implementation will lead to the gradual outlining of a basic methodology.

Given the vast machinations of the fashion industry today, computational fashion is barely a niche. How can this field attain the critical mass needed to cultivate a community of peers in open discussion about new concepts and approaches? Part of the solution will be the development of more generalized tools. Exposure and dissemination of research by individuals and corporations will play a large role in the expansion and progression of computational fashion. Most importantly, an audience outside the realm of research and academics must be found.

Although this thesis work was intentionally directed away from wearable computing goals of informational, rather than expressive, enhancement, I believe that the ability to do and receive things while on the go will profoundly change the way we situate ourselves in the world. Computation on the body is far from being a template for cyborgs or robots. Issues of mobility and utility are as relevant to computational fashion as they are to traditional clothing. I look forward to the blurring of boundaries, when hardware, software, utility, aesthetics and form are no longer distinct tasks or goals, but facets of a single stone.

The Future: Design

The most fundamental aspect to creating computational fashion is full attention to design at all levels. As a single person, complete implementation is extremely difficult; nevertheless each area of design – hardware, software, and form – must be presented as design that stands on its own, formal design as sculpture, hardware and software as engineering. Struggles with implementation are part of the process, but ultimately concept and quality of design in every aspect are the most crucial elements for meaningful research and creation to push forward.

Appendix: Glossary of Terms

bias - at a forty-five degree angle to the grain of woven fabric; allows some stretch in the fabric.

dart - a triangular fold or tuck for creating shape and volume in fabric.

EL - electroluminescence; an organic phosphor sandwiched between two conductive layers, which emits light when driven by an AC voltage.

grain - the direction parallel to the threads of woven fabric; structurally the strongest orientation.

IC - integrated circuit; the circuitry needed to perform a certain task, consolidated on one chip.

LCD - liquid crystal display; an addressable display device.

LED - light-emitting diode; a discrete electronic component that emits light.

microprocessor - a small integrated circuit capable of performing computation.

optical fiber - a long strand of transparent plastic (acrylic), coated externally with a transparent substance that has a different index of refraction from its acrylic core, causing light entering one end of the fiber to bounce within the strand until it exits the other end.

PCB - printed circuit board; manufactured circuitry, with circuit wires printed on a plastic base and holes or pads for attaching electrical components.

PIC - programmable integrated circuit; a brand of programmable microprocessor with input, output, storage and timing capabilities.

seam - the join between two pieces of fabric; usually stitched.

sensor - an electronic component that changes state (e.g. resistance) based on some stimulus (e.g. temperature).

stitch - a pattern of thread through fabric, either decorative or used for joining.

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