Subtle Garment Integration of Technology: A Case Study of the Business Suit

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Abstract

Integration of technology into standard apparel poses many difficult problems: for the consumer, integration in such a way that technology does not create physical or social discontinuities, and for the manufacturer, development of a production process for integrating technology into apparel. In this paper, we seek to specify the component factors of these problems, and propose a solution within the confines of the business suit.

The business suit represents a standardized garment system, containing pre-existing volumes created by padding or stiffening agents which create the 3-dimensional tailored shape. We propose exploitation of these volumes to house technology, without requiring a change in the aesthetic appearance of the individual garments or altering the user's perception of the garment system. Creation of stand-alone technology units in the form of garment inserts removes the need for high-level integration of the apparel and technology production processes.

Introduction

The field of wearable technology, especially that of garment-integrated wearable technology, is currently primarily largely academic research, which rarely ever reaches the commercial market. The reasons for this are many and varied. Many (but not all) of these issues can be classified into concerns of the user and concerns of manufacture. The impediments to user acceptance of wearable technology can involve the design of technology applications, the design of user interfaces for these applications, the physical comfort of wearable devices, and the psycho-social implications of wearing technology (which also includes the aesthetic design of the technology and the manner of wearable integration). In addition to user concerns, the process of getting a product to the user poses many additional impediments, stemming from the commercial manufacture of garment-integrated devices, which lacks a precedent for cooperation between the apparel and electronics manufacturing processes. In this paper, we seek to address several of these issues, most notably those which pertain to the physical integration of technology (comfort, appearance, and manufacturing issues) and to present a potential solution to many of the problems using a case study of the business suit.

The few garment-integrated technology products that have overcome significant obstacles and reached the commercial market have often avoided the issues of high-level integration of electronics and apparel production processes by using electronics designed as stand-alone units, which are then integrated into garments by way of special pockets, embedded conductors, or other minimal means of attachment. This solution has reduced problems with the actual manufacture of products, but success has been less evident in consumer acceptance of such devices. The reasons for the lack of mass-market acceptance are difficult to define, and are outside the scope of this paper. However, the aesthetic obstacles to wearing technology in an everyday application are clearly evident. Clothes carry with them cultural standards of appearance and use, and violations of those norms are often resisted by the general public. Integration of technology in a highly visible manner, while attractive to a certain target market, can be an impediment to more widespread acceptance.

To that end, our proposed solution makes use of the benefits of manufacturing a stand-alone technology (streamlined production, ease of care and use) while utilizing pre-existing garment volumes to house technology, instead of creating volumes on the surface.

Manufacture of Garment-Integrated Technology

Wearable technology today can be facilitated at three levels of integration: body-mounted, garment-integrated, and textile-integrated. Each level of integration creates its own challenges for manufacture.

Body-mounted: At this level, technology is integrated into a unit which is mounted for continuous wear on the body. This includes specially designed bags and packs, strap-on modules, and all configurations which do not make use of a standard garment. Body-mounted technology often presents the fewest complications in manufacture. The technology can be fabricated as a unit, and inserted into the wearable housing. Off the shelf technology can easily be made wearable by addition of straps or clips. The drawbacks of some types of body mounting include a marked decrease in wearability, as the physical shapes and interfaces of pre-existing technologies often are not designed for continuous wear or for body mounting, and an increase in visual perceptibility, for many such body-mounted technologies are either meant to be worn on top of or outside of the clothing.

Garment-integrated: This method of integration can be facilitated in a number of ways. The simplest and easiest to manufacture is the addition of special pockets and connector conduits to a standard garment. In such an instance, technology and garment can be independently manufactured, and the interface requires minimal alterations. In a similar configuration, technology can be fabricated in independent units which are then incorporated into the garment, either permanently or so that they may be removed at will.

Technology can also be integrated into garments by attaching circuit boards, sensors, or other technology directly to the garment. This can require coordination of production efforts between the garment and technology, for instance if elements of technology must be affixed to garment pieces post-cutting and pre-sewing.

Textile-integrated: This configuration requires a high level cooperation between technology and garment manufacturing processes. In such a structure, conductors and connectors must be woven, knitted, laminated or otherwise integrated directly into the textile, usually during production. Chips, boards and sensors must be affixed to the augmented textile, and conductors may need to be joined across seams.

Textile-integrated technology may also include the integration of computing elements or other technology directly into the fiber or yarn.

Many of the largest barriers to mass-marketing of wearable technology arise from manufacturing difficulties. However, clever design of the interface with technology may circumvent many of these difficulties, and allow the garment and electronics industries to ease into cooperative manufacturing.

Considering Wearability

When mounting anything on the body, physical comfort and wearability must be considered. Poor design of an intelligent garment or wearable device can counteract the intended functionality, because in most cases an uncomfortable garment or device simply will not be worn. When designing garment inserts, several important issues must be considered.

Thermal Management: The human body tightly regulates its temperature just below 100F while operating through environmental extremes of 68F to 138F [1]. Garment systems of all kinds incorporate thermal adjustability through layering, venting, and accessories. Integration of wearable electronics presents clothing forms a new challenge for thermal management, by adding the heat produced by certain components to that produced by the body. The smaller the area over which electronic components are distributed, the smaller the area their over which heat is initially distributed. Recent advances in miniaturization have not been paralleled by similar advances in component power consumption. As a result for a consistent level of functionality smaller components generally are hotter.

Excess heat can be removed from the body by means of conduction, convection, radiation, or evaporation. Conductive transfer from components is often facilitated through heat sinks. Without such a sink, the body often absorbs the excess energy from the component. It is important to incorporate a heat sink, and orient the heat transfer away from the body. Convective transfer can be facilitated by incorporating vents or spacer fabrics into the garment, to permit air circulation between the components and the body, which can also facilitate evaporative transfer through perspiration. Radiation is a less efficient (passive) means of transfer.

Impermeability: Most printed circuit boards (flexible or otherwise) are made of completely impermeable plastics and resins. While these materials are standard to manufacturing processes and provide the circuitry with necessary support and stability, any impermeable barrier too close to the body can be uncomfortable. Impermeable barriers can hold in heat and moisture, thereby reducing comfort and wearability. Moisture management can be facilitated through use of breathable or wicking fabrics, or by permitting airflow (through aforementioned spacers or vents) to permit evaporative cooling. Additionally, to preserve their functionality, wearable electronics need to be protected from perspiration as well as environmental moisture, such as precipitation or spilled liquids.

Mobility: The natural physical movements of daily life are habits which have developed given a perception of body area, or proxemics. [2,3] Adding bulk or volume to the body should not interfere with natural movements. Design must also take into account situation-specific movements, required for the accomplishment of a task. In more extreme situations, where weight is a factor as well as volume, weights should not interfere with stationary or dynamic balance. Locating weights close to the body's center of gravity can help reduce the perception of weight. [4]

Flexibility: Standard solid PCBs are often difficult to integrate into clothing or body-mounted forms because of their inability to conform (statically or dynamically) to the contours of the body. Flexible PCBs are available with optimal bend radii of 1-2 millimeters. The problem from a wearable perspective is that the flexibility of a finished board is dependent on the layout of the components it is populated with. The boards are only flexible outside of the regions populated with components. Aggressive flexion or torsion in a component populated region will weaken electrical connections and could cause components to be ripped free from the circuit board.

In order to use flexible PCBs in garment integrated wearable electronics the component layout needs to be designed such that components are clustered in bend and torsion stabilized areas, and connected together by unpopulated (and thus still flexible) PCB. Alternately, the design may be segmented with components distributed over many traditional inflexible PCBs joined together with ribbon-like flexible interconnections.

Durability: The highly dynamic needs of the wearable environment can be a challenge to the development of wearable electronics. Avoiding body flex zones (body areas of greatest change with movement) and incorporating flexible stabilizers into the structure of the electronics can help to merge durability and flexibility.

Sizing and Fit: If garment inserts are designed in such a way that the specific location on a given body part is important to the wearability, comfort, or functionality of the insert, individual sizing and fit can become a significant issue. The anthropometric variation in the human body across the population is significant, and hard to generalize. The less fit-specific an insert is, the more wearable it can be for a broad range of body types.

Peripheral Variables: These variables pertain to the situation of the user, the tasks the user will perform, and the other garments and accessories that must interact with the augmented garment. For instance, in this paper we will use the shoulder pad as an example integration area. This is a highly useful area in many garment systems, but should the user require the use of a shoulder-strap bag, it could prove quite uncomfortable should the weight of the bag press any electronic components into the user's skin.

As with any human-centered design, the variables to consider are extensive. The concept of embedding technology into garment inserts can also be applied to other garment types. Each individual garment system has it's own constraints, which must be addressed on an individual basis. Other systems are not as standardized as the suit, therefore the integration can be less generalized, however in many cases such integration is highly possible.

Integration of Technology into Garment Inserts

We propose the solution of garment inserts as a method of technology integration that allows the preservation of socio-cultural expectations, ease of manufacture of garment-integrated technologies, and garment care and maintenance practices consistent with the current norms.

We define clothing inserts as layers of padding, interfacing or other materials meant to give shape, strength or protective function to the garment. This definition is broad enough to include garment pads such as shoulder, knee or elbow pads, as well as less physically obvious inserts such as the layers of interfacing added to stiffen garment sections (e.g. the waistband, shoulder area, collar, or lapel). The added stiffness and bulk of these inserts provides a ready-made space in which small-scale electronics can be housed without visually changing the garment. [5], Figure 1 illustrates the areas commonly padded or interfaced in a suit. These are areas of increased volume or stiffness, which may be replaced with the volume or stiffness created by embedded technologies.

Figure 1: Common Areas of Padding of Interfacing in the Suit

The internal construction of the business suit, as illustrated in Figure 1, specifically uses layers of padding and interfacing to create shape. Creating flexible, molded, potentially removable structures in these volumes can facilitate the integration of technology without alteration to the visual appearance or physical comfort of the garment. In addition, subtle integration of technology can mitigate the social acceptance of wearable technology by minimizing the social barriers which arise when the popular concept of clothing is altered. [6].

Finally, garment inserts can maintain the independent manufacturing processes of the garment and technology, allowing each to be manufactured separately, and then combined with minimal adjustment.

Why the suit?

The three-piece suit has existed in some form since its conception by King Charles II of England in 1666. Charles's original intention in establishing the suit was to impart new cultural values to the nobility, emphasizing thrift, modesty, and economy instead of opulent extravagance. [7]

The suit of today is visually quite different from that of the 1600s. However, the visual form of today's suit is recognizable as early as 1800, when knee-breeches gave way to long pants. By 1900, the individual garments had taken on a visual form that has perpetuated (with minor adjustments) until the present day. The vest had also become an optional garment, removable without altering the visual recognition of a suit. [8]. Although the specific cut, fabrics, and ornamentation have changed dramatically from the 3-piece-suit of King Charles, the cultural values he imparted with the new style have remained embedded in the garment system. Charles's intention was to shift the values of the noble class, from a frivolous emphasis on extravagance to a reserved focus on thrift and modesty. The suit today still carries that cultural ideal, imparting power, competency, or responsibility. [9].

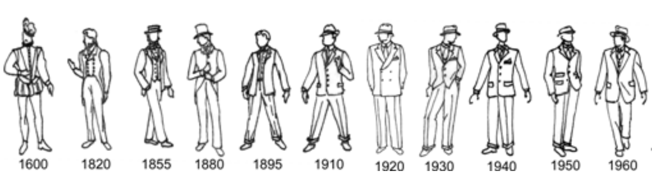

Figure 2: Evolution of the Men's Suit

As seen in **Error! Reference source not found.**2, the Men's suit has seen little alteration over the last century. Most change is seen in the width of lapels, the placement of buttons, and the configuration of pockets [10].

The visual standardization of the suit can be seen as a form of technological closure. Rhetorical closure occurs in the development process of a technology at a point where the "controversy" surrounding a new technology (the presence several different forms or variations on a similar design) is eliminated and a form of consensus is reached. [11]. The 1900 suit took a form that was functionally, aesthetically and economically successful, and that form has perpetuated since. Socially, the suit is the only multi-layered garment system in the western world that can be considered a "uniform" for a broad cross-section of the population: it is a standardized garment system that is not limited to a specific occupation or situation, or even class.

The business suit as a "closed" technology, having accumulated significant social significance and symbology, could not remain restricted to the world of men. As early as the first decade of the 1900s, tailored garments for women began to emerge, and women could occasionally be seen sporting a full male costume. By the 1920s, a women's version of the men's suit was an accepted fashion. The suit carried the same social connotation as for men, and was often worn by women to promote a distinctly feminine version of masculine power. Throughout the rest of the 1900s, the feminine suit continued to evolve with women's fashions, incorporating the same tailoring techniques and fitted shapes, but never achieving the closure of the men's suit [12].

As international trade and communication became increasingly possible in the 20th century, garments, like other visual cues, began to permeate across cultures. The western business suit today can be seen being adopted by many cultures across the globe, even cultures whose traditional dress is dramatically different from this kind of tailored garment.

The business suit is also a common part of the business environment, one that is often acknowledged as a prime application space for mobile and wearable computing. Because of the extensive computational needs of the business environment, and the increasing need for mobility and accessibility, wearable computing is quite appealing in this context. Additionally, this target market can often afford emerging technologies.

Construction and Manufacture of the Suit

The construction and manufacture of an individual garment needs to be taken into account in designing technology to be incorporated via garment inserts. The suit provides a useful platform, due to its relatively extensive built-in structures and volumes, as compared to other garments.

The tailoring process imparts a sculptured three-dimensional form to a garment. Shape is commonly created in the lapels, shoulders, collar, and sleeves.

Tailoring techniques use layers of interfacing of various weights and cotton batting to build forms into a fabric shell. The tailor's art is that of camouflaging defects and building flattering shapes on the human form. Shape is built in three ways, first by cutting the flat pieces of a garment and stitching them together to form a three-dimensional garment, then by pad-stitching together layers of interior materials (interfacing, batting) to create a reinforced curve, or finally by steaming woolen textiles and blocking them into shape.

Figure 3: The Interior of a Suit Jacket, Showing Layers of Stitched Padding and Interfacing

Modern suits are commonly available in three styles of manufacture: hand-tailored, made-to-measure, and ready-to-wear.

Hand-tailored suits: The hand-tailored (or bespoke) suit is the most expensive and time-consuming method of manufacture. The suit pattern is generated by hand, and the cut, style, and fit of the suit are specifically crafted to the needs of the individual customer. Many of the shaping steps in the tailoring process are done by hand.

Made-to-measure suits: Made to measure suits allow the customer to choose the style and fabric of their suit from a selection. The suit is then cut in a factory from a pre-produced pattern, which has been adjusted to the customer's measurements. The shaping steps in a made-to-measure suit may be done by hand or by machine. A tailor then may make final adjustments by hand or machine as a result of additional fittings with the customer.

Ready-to-wear suits: Sold completely finished except for the trouser length, ready to wear suits are designed require a minimal of hand work and only a single fitting to adjust the trouser length and buttons, and occasionally other minor alterations to the fit of the garments. Since each size is designed to fit a range of body types and styles, ready-to-wear suits very rarely fit as well as custom cut suits. Skilled tailors however are able to significantly improve the fit by making alterations to the coat sleeves, trouser buttons and adjusting the seat, waist, collar, shoulders, and chest. [13].

A benefit of the suit over other garment systems is the expectation that the final garment be custom-fitted is already incorporated into the process of purchasing a suit. Even off the rack suits assume a single fitting with a tailor to customize garment fit. Manufactured garment inserts with the ability have their profile adjusted post construction by the tailor provide a potential housing for wearable electronics that can be tailored to a larger segment of the population. However, the vast majority of clothing today is not custom-fitted. The growing interest in mass-customized fit in the apparel industry may prove valuable to the production of wearable technology [14].

Another benefit of the suit over other kinds of garments is that it requires less frequent cleaning. Barring extreme climates experts suggest a range of dry-clean schedules between once every five to twelve times the suit is worn [13] Because the suit is dry-cleaned, removable inserts may potentially be removed by professionals prior to cleaning, and no change in habits would be required of the user.

Example Application: The Shoulder Pad

In order to test the viability of garment inserts as an implementation space for wearable electronics the authors undertook the construction of a vibrotactile shoulder pad insert. [5] The example application, vibrotactility, is one that is highly useful within the construct of wearable technology. Since wearable technology can be designed to stay close to the body, it is one of the few structures of technology which can successfully make use of the sense of touch. However, vibrating motors are merely one example of the technology which could make use of the pre-existing volume of the shoulder pad. [5]

The first part of the study concerned the determination of the available volume in the shoulder area. To do this, an anthropometric analysis was conducted to determine the maximum available space in the shoulder pad for a range of sizes to fit the entire population. As shown in figure 4, several body landmarks were used to determine the maximum volume for a shoulder pad on an individual.

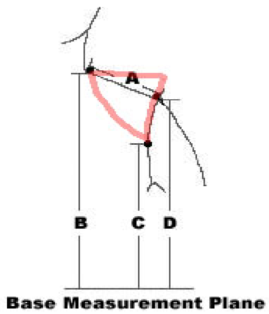

Figure 4: Body Landmark Measures

This maximum volume was determined by using the horizontal plane from the base of the neck as the absolute largest height for a shoulder pad. As a purely horizontal shoulder plane is rarely fashionable, that measurement (pad height) was adjusted from the maximum to determine a more reasonable shape.

In this case, the technology to be integrated into the insert was minimal, consisting only of 4-6 flat pancake pager motors. Thus thermal, flexibility, mobility and impermeability concerns were not relevant. The bulk and volume added by the shoulder pad was already present in the garment, and motors were added as individual units, both to preserve their independence of motion and to preserve the flexibility of the shoulder pad unit, consequently preserving the mobility of the garment.

User Results: Comfort

During subject testing for this study, 12 subjects were questioned concerning the comfort of the electronic shoulder pad versus the comfort of the standard shoulder pads intended to be worn in the jacket. All subjects found the electronic shoulder pads at least equally comfortable as the standard shoulder pads, and 3 recorded a perceived increase in comfort.

While the results of the work are still preliminary they effectively demonstrated the potential for garment insert integrated wearable electronics.

Conclusions

The integration of technology into garments poses a variety of unique problems: both from the perspective of the user and the manufacturer. For the latter, problems arise from the physical integration of technology and apparel during the manufacturing process. For the former, problems arise from the impact of technology altering the aesthetic and physical norms of clothing. Exploiting pre-existing garment volumes by incorporating technology into garment inserts allows the technology to minimize physical and visual impact on the user, while allowing the technology to be manufactured as a stand-alone unit, optimizing the interactions of the garment and technology production processes. This may provide a useful integration method for the suit, as well as for other garment systems.

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