The Role of Design in Wearable Computing

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Introduction

The purpose of this workshop is to provide a forum to discuss the role of design in wearable computing. Wearable computing spans a broad range of interests and expertise, not all of which can be adequately represented by a technical paper in an IEEE Computer Society proceedings. As wearable computing becomes more mainstream, and if it is to continue becoming more mainstream, it is important for ISWC to provide appropriate venues for presenting the latest advances in textile, fashion, and industrial design. The objective of this workshop is to come up with a set of recommendations on what the appropriate venues should be and to discuss what the important design issues are for wearable computing.

Wearable computing is an example of what I like to call “computing as a material.” Designers are comfortable with using computing as a tool, for example, editing photos and drawings or creating 3-D models. But with wearable computing (and to a greater extent, pervasive computing) the time has come to treat computing as the object being designed rather than as an instrument to use on the object being designed. Computing is intrinsic to the object being designed, and as such should be regarded as a new material. For this to happen will require people skilled at working in the margins between traditional disciplines.

I posed several questions in the call for papers, including the following:

What are the important design issues for wearable computing? How will addressing them advance wearable computing? How will addressing them advance the particular area of expertise, e.g., how will e-textiles advance the field of textiles?

Is the difference between a design contribution and a technical contribution simply an emphasis on wearable instead of an emphasis on computing?

Wearable computing has had some problems gaining legitimacy with computing researchers; are there similar problems for designers?

The questions, if not exactly controversial, were intended to spur people from a broad range of disciplines to contribute. I hope you will find the five papers included do indeed represent a range of disciplines. The range is by no means exhaustive, and with luck the workshop will encourage members of other disciplines to contribute in the future.

The workshop would not have been possible without the help and input of several people. The seeds for the workshop were sown in a couple of animated discussions I had with Despina Papadopoulos at a smart textiles conference in the spring of 2007. When I floated the idea at the ISWC program committee meeting, the PC members were very encouraging. Kent Lyons and Kristof Van Laerhoven accepted the workshop proposal and accommodated it in scheduling it with the tutorials.

Finally, please think of this workshop as the beginning of a conversation about how to encompass all of the many facets of a successful wearable computer. My hope is that this conversation will lead to an already great ISWC community being even better in its second decade than it was in its first.

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Blacksburg, Virginia
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Designing Wearables: A Brief Discussion

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Abstract

This paper has been used to highlight our thought on some of the issues that are to be raised at the Design Workshop. Including brief discussion on; how design fits into wearable computing, how evaluations of design contributions can be made, guidance for designers and submissions, interdisciplinary working practices and their usefulness to wearable computing, and of design issues applicable to wearable computing.

Our views are formed as designers and therefore will provide insight for the traditional 'non-designer' wearable computing community. We hope that this paper will encourage further in depth discussion.

This paper is intended to contribute towards establishing a valid set of recommendations, which will be used to drive the issues and implementation of design within the wearable computing community.

1. Design and Wearable Computing

The first question that we must ask ourselves is; What is design? It is a tricky question to ask in general, and is often a hot topic of discussion within the academic design community.

The Oxford English Dictionary defines ‘design’ as;

i. “a plan or drawing produced to show the look and function or working of a building, garment or other object before it is made”

ii. “the art or action of conceiving of and producing a plan or drawing of something before it is made”

iii. “purpose or planning that exists behind an action, fact or object”

From the definition we see that to design something means that it must be planned with a purpose in mind.

The design community is very diverse, covering a wide range of areas, from the harder engineering design to the softer artistic design. Design Activities range from integrated circuit design, textiles, system design, interiors, industrial design, software user-interface design and fashion design. Each has different working practices and measures of assessment.

‘Design’ within the wearable computing community, seems to be seen as the softer end of the spectrum. Design in wearable computing, is often associated with fashion shows, which is great for media coverage, but misses the point.

The design of personal computers was once just about putting components into beige boxes, with command line interfaces and ‘green screens’. Nowadays they come in a wide variety of sizes, shapes, colours and materials, made possible by the redesign of the internal hardware components. The most striking difference for the everyday PC user is the move from textual commands to the Graphical User Interface (GUI). The industrial design of personal computing is becoming ever more important and is highlighted by the current Apple advertising campaign of Mac versus PC, or design versus functionality. This is a general phenomenon that occurs as technologies mature and consumers expect more from the products, expecting them to fulfill functional and aesthetic/emotional needs [1].

Design for wearables is more than just putting electronic components into fashionable clothing, the whole system should be considered as part of the design process. These should include; physical form, electronic components, GUI, physical interface and embodied product value [2].

There are several areas of design which are specifically relevant to wearable computing, software design, in particular user interface, and to a larger extent user experience, hardware design (which is at the more traditional engineering end of the spectrum), and wearability.

Studies around wearability have not featured as prominently as one may expect, although there have been several recent papers at ISWC which have examined the issue [3, 4, 5, 6 & 7], they still remain very much a minority. The term ‘wearability’ can be used to describe the process and experience of donning, wearing, using and removing a wearable computer 'garment'. In addition the care and maintenance of such garments require further study before wearable computers can be developed into true mainstream products.

1.1 The Benefits of Qualitative Analysis

Assessing the success of a particular design is very difficult as assessor opinions are often subjective, having cultural and personal influences. Designs could potentially be assessed against the original design
specification, which would be unique to each project. Using criteria such as; is the designs functionality fit for purpose?; and is the design capable of solving the described problem?

There are many different evaluation techniques that could potentially be applied to the design of wearable computers.

Reductionist approaches such as [8] and [9] enable us to distinguish efficient methods of interacting with wearable computers. However tests such as these are conducted in controlled 'laboratory' conditions, and may not accurately reflect the circumstances encountered in the real world. From a designers perspective some of the most interesting results within these papers is found amongst the qualitative data. Comments such as: “I feel if the device was larger it would be easier to manage.” [9], or (with reference to a gesture based numeric entry system) “I made use of the fact that '8' is a full circle [and] later learned other patterns” [8] are potentially of great benefit to the design process. This type of insight is invaluable to a designer wanting to improve an existing product or wishing to seek new interaction techniques.

Qualitative information is highly prized with the design community, identifying softer and sometimes unexpected results, which could not be generated using quantitative techniques. We feel that a greater emphasis should be placed upon qualitative evaluation methods such as, observing people who are interacting with wearable computers in real world scenarios.

It would be a positive step to have this type of qualitative data moved from the small 'discussion' sections at the end of papers and instead become the core of detailed ethnographic studies.

2. Design Submissions & Presentations

Design conferences usually use a traditional paper submission process which is not too dissimilar from IEEE submission requirements. For instance the submission guidelines for the 15th International Product Development Management Conference [10] states two of its requirements for papers as:

i. The theoretical base must be made clear, and references to already-existing research in the field must be made explicit.

ii. Priority is given to research which has an empirical basis. This means that conceptual discussions without empirical tests or basis will be accepted only exceptionally.

However there are other design conferences that do not have such tight requirements, allowing submission to be a more creative. At these conferences there are usually discussions of produced works and the processes employed to achieve them. This is done much in the same way as the wearable computing community, although the content is very different. Papers at design conferences frequently take the form of case studies.

Design conferences often have broad outlooks, encouraging inter-disciplinary/cross-disciplinary discussions. For instance at the 2nd International Conference on Design Principles and Practices, encompasses the perspectives and practices of: “anthropology, architecture, art, artificial intelligence, business, cognitive science, communication studies, computer science, cultural studies, design studies, education, e-learning, engineering, ergonomics, fashion, graphic design, history, information systems, industrial design, industrial engineering, instructional design, interior design, interaction design, interface design, journalism, landscape architecture, law, linguistics and semiotics, management, media and entertainment, psychology, sociology, software engineering, technical communication, telecommunications, urban planning and visual design.” [11]

As you can see this scope is vast, with many areas which would not necessarily be considered by non-commercial designers to be a concern of design. This phenomenon is endemic to the design community; which has constant desire to know more and try to form new improved solutions to design problems.

The design community itself is in a current state of flux, this can bee seen in the contextual statement for the 2008 Design Research Society, “Designing seems to be moving into a new era, the disciplines that have framed our work are reshaping themselves, new kinds of designing are emerging and we are not yet able to define these new and hybrid professions, some created by people not previously thought of as designers”.[12] It could be noted that the wearable computing community currently seems to be in a similar state of flux.

There seems to be no easy way to absolutely pin down a limited set of criteria which a design submission must follow, as is with design, it can sometimes be a little unpredictable.

Design submissions for wearable computing may initially follow the standard route for submission, or may be a shortened proposal route, which would not require a full paper to be submitted, but would require an in depth demonstration and reflection upon the work produced.

3. Guidance for Designers

Submissions should clearly outline the design methodology and methods used. It should be demonstrated how problems were identified and how the effectiveness of the proposed design solution was assessed.

Designers of wearable computers should be encouraged to develop new methods for designing and evaluating their solutions. This could include discussions about collaborative working practices and the development of new, shared languages.
The development of wearable computers pose complex design problems. Complex design problems require more knowledge than any single person can provide because the knowledge relevant to a problem is usually distributed among several stakeholders. This can often bring opposing and controversial viewpoints together creating a shared understanding among the stakeholders, potentially leading to new insights and ideas. [13]

When using a collaborative design process (sometimes called Co-design), all stakeholder perspectives are included during the design process, this is generally perceived to increase the quality of designs.

In more advanced forms of Co-Design users are included in the design and development process (this is sometimes referred to a Participatory Design). This adds another level of complexity to the design process, but can provide high level of insight, for the other stakeholders in the process.

Some of the broad issues of collaborative design can be found in Scrivener’s book ‘Collaborative Design’. [14]

Ariyatum has proposed an optimized collaborative new product development process for smart clothing.[15] As part of Ariyatum’s analysis it is stated that one of the major hurdles for “the conventional structure of NPD models fails to demonstrate the different work methods of these two sectors [electronics & fashion]. Therefore, a new way of presenting NPD model is needed in order to enhance better understanding about work, responsibility and the communication within collaborative teams.” [16] This also highlights two major factors in collaborative working, the first is understanding responsibility and the second is communication. Ariyatum’s model is based on a combination of the ‘Six Hats/Parallel Thinking’ method [17] and Boundary Shifting.[18] The proposed model provides valuable insight into a potential model for wearable computing.

Wider qualitative studies would also be of great interest to the wearable design community. These studies could include investigations into the use of new or existing products, tools and other artifacts. Provide insights into end-users, including: their methods of working, problem-solving and communicating. And develop detailed understandings of the environment in which wearable computers could operate effectively.

4. **Requirements for Tenure**

There is a growing practice-based research community within art and design in the UK, Europe and Australia. Practice-based researchers face complex, fast-changing structures and expect methodological debates. The practice-based research community may provide valuable insight for tenure track dossier development.

There is a bi-annual conference, Research into Practice, which has been running since 2000 [19].

Another conference AVPhD, concentrates specifically on practice-based audio and visual arts at PhD level [20].

The majority of practice-based research literature encompasses PhD level study. Requirements for tenure could potentially be drawn from this literature debate. There is however ongoing debate in this area, that needs to be taken into consideration.

The main concern of the practice-based research community is to explore practice as a form of research. Art & design education, originates from the medieval craft apprenticeship model, this model has evolved over the centuries, its current incarnation is now required to fit into the paradigm of conventional (scientific) research model. However art and design do not fit the conventional model well, Marshall & Newton illustrate this, “Scientific inquiry, like any form of inquiry exposes only certain kinds of problems and validates only certain kinds of solutions. The kinds of problems scientific inquiry has most difficulty in exposing are precisely the kinds of problems and situations faced by practitioners: problems and situations that are complex, uncertain, unstable, and unique, often articulated across conflicting value systems.” [21]

Dilnot states that “In design research it is the process of producing an artefact which is key”[22], this is a major factor for practice-based research in art and design.

In the wider debate about types of research Boyer states that there is not just one kind of research. There are 4 enterprises of the academy model, points 2 & 3 are of relevance to us in this discussion.

Enterprise 2: A scholarship of application. Refers to the application of knowledge to consequential problems, and the generation of new knowledge out of practice.

Enterprise 3: A scholarship of integration. Relates to putting isolated facts into perspective. Refers to the synthesising tradition in academic life. Integration is about making cross disciplinary connections and contextualising specialist knowledge for broader audiences.[23]

The University of Wales, has an official policy for the submission of practice-based research at Masters and PhD study, “the thesis may take one or more of the following forms: artefact, score, portfolio of original works, performance or exhibition. The submission shall be accompanied by a written commentary placing it in its academic context”.

This does, of course, need some interpretation, and the University of Wales, Newport runs several practice-based research training courses each year, for research students and staff responsible for their supervision.

The UK Academic Research Assessment Exercise (RAE) has a set of criteria for assessing works of Art & Design (Panel O, Unit 63). This may provide valuable insight for the development of assessment criteria. There is specific guidance for applied and interdisciplinary research [24]. Great emphasis has been placed on the
contextualisation of outputs submitted for assessment in the case of Art & Design research. This is not required by other assessment panels.

5. Legitimacy of Wearable Computing
Wearable computing does not fit neatly into any particular category, which is why it may have had some legitimacy issues. To some extent, designers have also suffered from this same issue where wearable technologies are concerned.

This issue is highlighted by the Nike+ iPod product range, which cannot easily be purchased as a whole unit in one outlet. The music player and shoe insert are purchased in an electronics store, and the footwear at shoe shop.

The wider issue of social acceptability (or lack there of) of wearable computing needs to be addressed.

In an historical context media coverage of wearables seems to have been detrimental, conveying an image of the ‘uber-geek Cyborg’. More recently solar powered bras and ‘flashy’ wearable gadgets have caught the eye of journalists keen to hype this technology trend. As is often the case with advanced technologies, they are hyped too much too early, when they are still not fully developed. This can lead to public disillusionment fueled by unfulfilled promises.

This is not a unique problem for wearable computers, during the 1990’s internet users were often reviled as unsociable loners or quixotic cyber warriors.

6. Interdisciplinary working practices
The Smart Clothes and Wearable Technology Research Group (SCWT) is looking at bridging the gap between science, technology and design in addressing the new industrial revolution that is taking place as technical textiles and garment engineering merge with electronics and communications. This demands creating a new shared language, bringing together experts from disparate study backgrounds and cultures. The research is led by a design methodology that approaches clothing design from an end-user led perspective that is better understood in product design than by traditional creative fashion and textile designers.

SCWT has been successful in attracting funding from the UKs joint research councils who have collaborated in prompting cross-disciplinary research that aims to address the demands of a growing older community. Our ‘New Dynamics of Ageing Network’ is looking at design-led applications for technical textiles in functional clothes, and related textile based products with wearable technology, in areas that promote health and wellness for older people.

The starting point for functional clothing development is the concept of the tried and tested military layering system, which has been widely adopted by performance sports and corporate wear. This system has a moisture management base-layer sometimes referred to as a second skin. With modern textile fibre developments and an infinite range of fabric constructions and finishes, smart garment system design is becoming increasingly sophisticated but with leading edge innovation normally restricted to top athletes.

This research team has the expertise to engage in the research and development of a generic garment layering system, for men and women, that address fit, movement, predominant posture, moisture management and thermal regulation to aid the comfort and well-being of an inclusive market. This type of engineered smart garment system provides the basis for the application and/or embedding of wearable electronics.

The group includes members from the social sciences, computing, clothing, textiles, medicine, design, ‘older’ users and industry partners. The participants provide a core of knowledge that enables the group to explore potential wearable products and services. Through the active participation of the main stakeholders, including end-users, proposed products can be assessed for: technical viability, social acceptability, commercial feasibility and possible integration into existing medical and social care systems.

Such collaborations are seen within the wider design community as essential in developing new technological products or services.

7. Design Issues for Wearable Computing
There are many issues that the wearable community should be addressing. We feel that there seem to be several ‘important design issues’ which need to be addressed; Wearability, Wash-ability/Durability, Security & privacy, and Ethics.

Each poses its own set of problems, but by looking into each issue the wearable computing community will be improved as a whole.

The wearable computing community could also consider how non-computer experts might get involved: for example, can a route for involvement be developed, making it easier from them to contribute? This does not imply any need to compromise the standard of submissions or the quality of debate.

There are also possibilities to provide new physical HCI and UI design processes and solutions for wearable computers in real world environments.

From a wider perspective the involvement and incorporation of Mobile, Ubiquitous and Pervasive computing communities may be of value to wearable computing. This is a discussion that is already taking place, but may need to be looked at in more depth, identifying key areas of overlap, for instance interoperability standards.
There is also the potential for development of a Design manifesto for Wearable Computing analogous to that proposed by the UK Ubiquitous Computing Community.[25]

Encouraging positive social awareness of wearable computing by the creation of a ‘Promotional Board’ The ‘Promotional Board’ would provide a reference point for the media and the public. Allowing a greater level of control over the type of publicity that is generated for the community. Possibly allowing access to extracts/examples from ISWC proceedings, which is currently unavailable to the public.

8. Summary

There is an obvious need for the involvement of scientists, but also for a level of undersigning during the assessment process, taking into account that scientists, but also for a level of undersigning during the assessment process, taking into account that qualitative design processes can add value and are valid techniques.

This lack of understanding is endemic of wider issues of collaborative working practices. Initially when two communities begin to work together there is a lack of understanding and frequent misinterpretations are made. Effective collaborative working practices will need to be developed for working with wearable computing.

Hopefully we have highlighted the fact that further discussion is needed into the many interesting issues involved in incorporating design into wearable computing.

9. References

A Case (and Case-studies) for Sketching in Hardware
Tellart, llc.
Matthew Cottam, Brian Hinch, James Hsu, Nicholas Scappaticci, Jasper Speicher, Katharine Wray

Introduction

The design process is heavily dependent on a prototype and revision cycle, and for years industrial designers have been creating low-fidelity sketch models out of foam, wood, fabric, etc. – whatever materials were available and easily molded into the three-dimensional shape of the objects they imagined. Graphic designers have been doing the same with layouts and interface design – the first step of the process is a sketched layout, and through subsequent revisions and layouts they eventually reach a final design.

This process breaks down when it comes to prototyping or sketching digital interactive products – most designers, and even most engineers, lack the ability to model or quickly prototype the most important aspect of the electronic object they are designing: the way that the physical actions of the user translate into the digital response of the system, or vice versa. It is the translation from physical to digital that defines the interaction between the user and the digital object; the interaction between the wearer and the wearable.

Over the past 7 years Tellart has been developing design processes which allow technical novices to “sketch” the interactivity of digital products with actual electronics – including sensors, actuators, and RFID technology. One recent iteration of this toolset, Sketchtools NADA, allows you to easily control these electronic systems using a computer running Adobe’s Flash CS3 (an existing multimedia software platform) or Java, and a Make Controller (an open-source physical computing platform, made by Making Things). NADA allows the user to control the Make Controller’s inputs and outputs using Flash or Java, which also gives them the opportunity to create meaningful on-screen interfaces to work with the physical components. For example, using Flash’s basic drawing and animation tools, a Make Controller connected to a light bulb, and the NADA extension, a user could quickly draw a slider bar to dim the light bulb, rather than outputting a series of numbers.

NADA allows both technical novices and the technically advanced to “sketch” with hardware using tools they are familiar with – Flash in the case of the designer, and Java in the case of the engineers. We believe that leveling the playing field and providing multiple disciplines with the opportunity to experiment with human-digital interactions using a similar platform enables more informed design decisions and facilitates the communication process between disciplines.

It has been used in both education and industry to facilitate the product development process in multidisciplinary physical computing projects, including some wearable computing concepts. This paper presents three case studies of multidisciplinary projects that used sketching with hardware and NADA throughout the product development cycle to create thoughtful and innovative solutions.

These case studies are examples of our experience working at the intersection of design and engineering on physical computing projects, as faculty and participants. This is not a structured proposal or the result of a research project – it is the documentation of what we believe are successful examples of multidisciplinary work in a physical computing setting.
Educational Case Study 1
Rhode Island School of Design (RISD) Industrial Design // Brown University Engineering

THE STANDER Assistive Design Studio

Students in this RISD/Brown collaborative studio worked to redesign the “stander” – a product which allows a physically handicapped individual, who is otherwise unable to stand, to be put in a vertical, weight-bearing position. In order for the user to remain upright, unaided, and in the correct posture, the stander must provide just enough pressure in the areas of the chest, buttocks, and knees to provide support while still allowing for the greatest weight bearing on the body’s joints and muscles.

As users of a stander are often physically and mentally handicapped, they can provide little to no specific feedback as to the comfort of the stander, the points of pressure, and the amount of weight they are actually bearing on their own.

Without the normal avenues of feedback available, the designers turned to NADA and a network of strategically placed sensors to get feedback throughout the sketch modeling process. They embedded the pressure sensors in key places in the fabric of their sketch models, and used the resulting data to inform their design of the system’s straps, padding, and positioning.

The students also fully prototyped a “smart stander” system which caregivers can use to monitor the stander’s usage and access a wealth of information about the user’s progress. They designed an Adobe Flash-based interface that used the sensor data to provide clear and understandable interpretations of the user’s experience and needs.

Allowing the students to prototype the stander system using sensors and electronics not only informed their final design of the product, but encouraged them to create an intelligent and digitally enabled product.
Educational Case Study 2
Rhode Island School of Design (RISD) Industrial Design // Brown University Engineering

HAZMAT SUIT Collaborative Studio
This studio was tasked with improving personal protection equipment, also known as hazardous material suits, for Emergency Medical Technicians (EMTs) working in contaminated.

The requests for improvement ranged from a friendlier looking suit that would be less intimidating to the public, to a suit that could be donned in a shorter time than the existing suits, even by seconds.

The students took it a step further and designed a suit that could be donned entirely without assistance and improved the time by minutes.

They added force resistant sensors to the fingertips of the thick chemically resistant gloves to allow the suited EMT’s to check their patients’ pulses, and prototyped communication devices that were fully integrated into the protective face masks.

After prototyping these improvements, they were given the opportunity to show their work to local EMT’s, and the feedback was overwhelmingly positive. The ability to show working prototypes to the end user, as opposed to just traditional “looks-like” models, was invaluable.

This project was featured in Metropolis Magazine. The following quotes are student reflections on the collaborative prototyping and development process.

My learning was not limited to factual information. As an Engineer working with Industrial Designers, I learned about the importance of drawing ideas, making sketch models, prototyping...the most important experience was learning how to start with a topic, form an idea for a project and turn that idea into a developed prototype.

Demetrious Harrington, 1st Year Grad. Student, Brown University

From the engineers I learned how to look very practically at the design process...from the industrial designers I learned the importance of perfecting designs in sketch models prior to completing a more final prototype.

Montana Cherney, 2nd Year Grad. Student RISD ID
Educational Case Study 3  
UMEÅ Institute of Design, Sweden

ACTIVE DESKTOP Repetitive Strain Injury Workshop

In this two week long workshop (part of a larger experience design course) students at the Umeå Institute of Design in Sweden used NADA to prototype innovative methods for encouraging a more energetic “desk-job” experience.

The students, who came from a variety of different undergraduate backgrounds ranging from Computer Science to Psychology, were taught some basic physical computing concepts and given an introduction to the NADA platform.

As a workshop theme, they were asked to tackle the problem of “repetitive strain injury”, or RSI, the name for a group of conditions common in computer workers and assembly line workers. The conditions (carpal tunnel syndrome is a well known example) arise from too much time spent in a poor posture position or too much repetitive muscle activity.

These projects, unlike the other case studies, were never meant to become final products – the time constraints of the workshop necessitated that they end up as sketch models. Rather than sketching with pens and paper, or with traditional modeling materials such as foam, wood, or fabric; they used sensors, actuators, and on-screen interfaces that realistically prototyped the physical to digital interaction.

The descriptions of the projects shown at left are as follows, from top to bottom:
(1) A half-hand glove, comfortable enough to wear while typing, and rigged up with flex sensors that control an on-screen animated game. The game encourages RSI-fighting hand exercises.
(2) A wireless “run-away mouse” that senses the user’s attempt to grab it, then uses servo motors to run away and race around the desktop. The user has to make a few therapeutic reaches for it before it will calm down and let itself be caught.
(3) This sweater has accelerometers built into the sleeves and forces the user to engage in some physical activity before he or she can continue working. The user’s screen is occasionally obscured by blocks of color, and in order to keep working he or she has to ‘wipe’ the blocks away with a few exaggerated arm movements.
Conclusion

We thought initially that interdisciplinary work between designers and engineers would expose a big cultural gap, but it didn’t – there was however, in most cases, a large intellectual gap. We didn’t want to make a design course for engineers or an engineering course for designers, but we wanted to have a common challenge and address both Industrial Design and Engineering aspects of the product development cycle in a twelve week studio course series.

Engineers are used to being supplied with a detailed project brief at the outset of work, including things like a human needs document, a system requirements document, etc. – all very quantitative in terms of how you measure whether or not you’ve completed your challenge. Few of the engineers had ever built anything with their hands – maybe they had used a breadboard, but many of them had not even soldered, much less welded or used a table-saw.

Designers, on the other hand, feel that if you have already solved for human needs and systems requirement, most of the design work is done. They are comfortable starting with extremely vague assignments, and are used to having the challenge of defining their design problem as a first step. They rely on sketching and hands-on ideation as a vehicle that will reliably take them from everything/chaos to a specific set of constraints/order, but they do tend to have limited math and science skills.

Engineers were generally quick to assimilate the culture and strategies of Industrial Design, partially because everyone has some experience with design; whether you are a hair dresser, dentist, car mechanic, etc. you have developed an appreciation for things like “the right tool for the job” and a quality made product versus a cheap feeling and performing product. For example, we once asked everyone in a class to pick out a well designed object and a poorly designed object from their apartments, and bring them in. There was no overall difference in how sensitive and insightful the choices were.

We chose electrical and software engineering as the space where we decided to level the playing field a bit in the form of NADA. We wanted to allow designers to sketch with the materials and tools of electrical and software engineering without extensive training or natural aptitude for math. A majority of our focus was to elevate the designers capacity to think and communicate in the terms of engineering, but we also wanted to involve the engineer and create a tool that would enable collaboration, not one that would suggest that designers can do the jobs of both designers and engineers.

We have had plenty of success using NADA in multidisciplinary academic settings, as well as within our own company – a team made up of graphic designers, industrial designers, computer scientists, and engineers. We use NADA to prototype and ideate electronic devices and systems in a way that wouldn’t be possible without a physical computing toolkit, and it places us in a unique position as a company.

We saw that installation and configuration of student machines can be tricky, and so future development may involve running the system off of inexpensive common mobile devices. Also, NADA still requires some coding and technical knowledge, which can be a stumbling block to unsupervised first time users. We plan to further develop the interface so that it can be more accessible to technical novices and first time users, while still developing advanced features that require in depth knowledge of the coding and processes involved. We also plan to integrate NADA with other physical computing toolkits (e.g. Arduino) to expand the options of the users.
Rant: Academic Hostility to Design Innovation
(Or, the Tyranny of Evaluation Revisited)

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1. Introduction
This essay was inspired by Henry Lieberman’s paper “Rant: The Tyranny of Evaluation” [1] and the exchanges that it sparked. I am hoping to keep the conversation alive—and broaden its audience to include the wearable computing community—by contributing another “not so serious provocation” [2] in the same tradition.

Lieberman’s paper describes how expectations of scientific evaluation hinder human-computer interaction (HCI) research. I believe similar problems pervade most computer science research communities, particularly experimental (system building) ones like wearable computing, since almost all of these are eventually (ultimately?) concerned with HCI. This paper describes why I believe design is marginalized and argues that we must rethink academic attitudes and structures to welcome design innovation if our communities are to remain relevant.

The boundary between scientists, on the one hand, and engineers and designers, on the other, is fairly clear. Scientists are on a quest to understand the natural world while engineers and designers build useful things. Scientists adhere to the scientific method: they generate hypotheses and then test these hypotheses through experimentation. Engineers and designers follow a different methodology. They too generate hypotheses of sorts, but rather than speculate about the way the world works, they develop building plans or blueprints. Then, before they can conduct evaluations, they must implement these plans. They follow a modified scientific method: they generate ideas, implement those ideas and then evaluate the implementations they’ve built.

So, what distinguishes a designer from an engineer? The boundary here is fuzzier, but for the purposes of argument, let us say that designers integrate the fundamental materials and tools developed by scientists and engineers into new artifacts. Designers innovate at a high level, building complete systems—which introduce new applications of technology—that humans interact with.

In my experience—attending conferences and reading, submitting and reviewing papers—computer science communities give disproportionate weight to the evaluation step in the “idea, implementation, evaluation” process. A paper that details the testing of a minor adjustment to an existing technology is more likely to be accepted by the main wearables conference, the International Symposium on Wearable Computers (ISWC)—and most computer science conferences—than a paper that introduces an entirely new artifact, but lacks extensive assessment.

The idea and implementation steps of technology research—where the lion’s share of innovation takes place—have been deemphasized. Communities are so fixated on testing that they have lost sight of the big picture. For advancements that are straightforward to test (we will coarsely define these as engineering advancements), the effects of this focus are minimal. But, for developments that are more challenging to validate—design contributions, in particular, which require testing with human subjects or hard-to-quantify evaluations—the effect is crippling. Design innovations are dismissed because they lack rigorous assessments. Design research progresses in incremental steps that can be easily tested and big ideas are left unexplored.

2. Why Is Design Innovation Undervalued?
Why have computer science communities developed this way? Why is design innovation embraced by the commercial sector and marginalized by academia? Why are disciplines that should be especially supportive of creativity and invention dismissive of design and therefore crucial technology advancements?
2.1. Computer Scientists Suffer from an Inferiority Complex

As Henry Lieberman put it, computer scientists have “physics envy”. We wish we were scientists. In science, hypotheses must be supported by mathematical proof or physical experiments. The goal, after all, is to understand the world. Scientists are not interested in supposition but fact. Computer scientists yearn for this certainty. A 1994 study conducted by the National Research Council detailed the difficulty implementation focused computer scientists face in gaining academic acceptance and tenure [3]. Though now rather dated, the report does an excellent job of describing how experimental (creative) results are not valued as much as theoretical ones.

In some branches of computer science it’s possible to conduct scientific assessment. Characteristics of algorithms and programming languages can be detailed with mathematical proofs. Getting into slightly fuzzier territory, artificial intelligence researchers can verify how well their algorithms and programs perform on specific data sets. But, upon entering the design fields of computer science (user-interface design, programming language design, wearable computing design), evaluation suddenly becomes completely messy and unscientific. How in the world does a researcher prove that a design is a good one? Any computer scientist who builds systems that are used by people is faced with this question, and it is saturated with uncertainty. What does good mean? Good for who? Good relative to what?

How does academia cope with this dreadful problem? Well, since we must be scientists, we must have scientific evaluations. Since we must publish papers (and cannot devote years of research to each conference submission), two basic paths are encouraged:

1. Design and build things that can be easily evaluated. Innovate in little pieces or incrementally improve previous designs. (Tellingly, the 1994 report cited above quotes a number of researchers who describe how the academic system forced them into this style of investigation.)

2. Forget about building things, just evaluate. Become an anthropologist, a psychologist or a sociologist. Leave the task of designing new technology to the commercial sector.

Each of these styles of research is valuable; assessment is undeniably essential. But, these paths should not be the only ones possible; evaluation should not be the primary priority for technology research. In the current academic culture, nothing is given the same amount of attention or weight that evaluation is, and we have thrown the baby out with the bath water. We have lost touch with the most important steps in the process, the things that are most essential to technology advancement: ideas and implementation.

One might scoff at this argument, saying “There is nothing that precludes work on ideas and implementation in the academic structure. Requiring rigorous evaluation doesn’t mean that you can’t introduce new ideas or implementations, it just means you have to prove that these contributions are valuable”. But, the truth is that the emphasis on evaluation makes taking any path other than the two described above very difficult, creating an environment startlingly hostile to innovation. Prospective design innovators face a wicked academic double whammy.

2.2. Innovation is Hard

First of all, innovation is hard! Designing and building completely new systems is hard. Coming up with a new idea requires creativity, extensive scholarship, and deep familiarity with the materials and tools available for implementation. Once an idea is deemed promising, its realization is non-trivial. Since the idea is new, building the system is a labor-intensive task plagued by uncertainties. Building a prototype invariably requires several design-build iterations, and often, after considerable investment, the designer is forced to abandon her idea as unfeasible.

It’s much easier to modify an existing design or stay away from designing comprehensive systems and just tackle little pieces of them. It always requires more work to build a completely new device than to make an incremental change to an old one. Similarly, it’s always easier to tackle small discrete problems and avoid the big picture. In short, innovators do much more work coming up with ideas and implementing them than do “incrementalists” of any stripe. This is the first whammy.
2.3. Innovative Designs are Hard to Evaluate
Here’s the second: innovators not only have to put more work into designing and building systems, they have to put more work into evaluating them. It’s much harder to test out a new design than an incremental change to an old design or a small self-contained new development. It’s also much more difficult to build a new system and evaluate it than it is to evaluate an existing system, the anthropological approach.

One might start by asking “does the system accomplish its intended task?”, a seemingly easy question. But, for many interesting innovations this is actually a difficult thing to answer. Many great designs aren’t improved versions of existing tools. They don’t make existing tasks more efficient. Rather, they open up entirely new realms of activity, empowering users to do things they simply couldn’t do before. For these types of systems the questions one wants to ask are open-ended, exploratory and not easily quantified. What do people do with the system? Do people voluntarily adopt it? What do people learn from or with it? How does their use of it change over time? How does it impact their lives? These types of questions are best answered initially by exploratory qualitative studies, (that are not favored by academia), and eventually by longitudinal studies of large groups of people over long periods of time, (that are time consuming and difficult to execute).

Even systems that are designed to accomplish definite goals are challenging to assess. When the system is new, how do you evaluate it? There’s often nothing to compare to! How do you know when a system does a good job at its intended task? Should the designer build one “good” design and one “bad” design to have a control group and an experimental group for his study? How does he define success? If, in the course of a study, seven users dislike the system, two love it and one becomes passionately engrossed in it, should this be deemed a failure? How much testing needs to be done before the system is declared useable or useful? (See [1] for more examples of dizzying assessment problems.)

2.4. It’s Easy to Assess Form and Hard to Assess Content
The academic paper reviewing process delivers the final blow to pioneering designers. As a reviewer, it’s easy to tell when a paper is well written; it’s easy to tell when it’s well organized; it’s relatively easy to assess the author’s research methodology; and easy to see when a paper fits an expected form: containing an idea, an implementation, and an assessment. It’s much harder to identify and appraise the contribution that a paper is making. Evaluating a paper’s content requires expertise and careful reading and reflection. One has to understand the contribution the submission is making and be familiar enough with the field to know whether or not it’s an important one. It’s hard to spot innovation. You have to be paying attention and you have to be knowledgeable enough to recognize it when you see it.

Most reviewers devote considerable time and attention to their assessments, but we all know that reviews are sometimes low priorities—less pressing than getting a paper written or a project built. Papers are typically accepted only when there is reviewer consensus; one negative review is usually enough to get a paper rejected. The result is that safe, good papers—papers that follow a familiar form, papers that are easy to give positive reviews to without a lot of thought—are accepted, but outstanding design papers—papers that pay more attention to implementation details, papers that likely lack quantitative evaluations and stray from the traditional form—are often rejected because of one bad review, even if several others applaud their excellence. (To help alleviate this problem, perhaps reviewers should be allowed to rate the care and attention they’ve given to a review in much the same way they rate their own expertise?)

The bottom line is that it’s easier to develop and evaluate an incremental contribution than a revolutionary one, and then the incremental contribution is more likely to be rewarded than the revolutionary one because it adheres naturally to academia’s expectations, structures and traditions. Given this climate, why would anyone want to do anything but make small adjustments to existing technologies?

3. How to Fix the Problem: Academia Must Provide an Explicit Place for Design Innovation
Conferences are the forums that we use to explore cutting-edge ideas and new developments. They should support, even provoke, conversation and self-examination. Design innovations provide unique sparks to discussion and reflection, reminding us of the roots of our field and its relationship to the rest of the world. Conferences like ISWC—communities that explore cutting edge applications of computation—have already been more welcoming to
design innovations than most computer science conferences. They would be further enriched if they began to explicitly welcome contributions that stressed ideas and implementations as much as evaluation.

*This does not mean lowering the standards of the conference.* It means thinking about a different style of assessment, an assessment that takes into account the unique challenges of design, one that recognizes the work that goes into designing and building a novel device, and acknowledges that great designs, which are beautifully implemented, are crucial contributions to the field.

*This does not mean abandoning evaluation* and this does not mean, as Shumin Zhai put it, turning design into a “faith based enterprise” [2]. Making room for conference papers that focus on design and implementation does not imply that evaluation never takes place. First of all, in the proposed structure, designs would be evaluated (qualitatively) not only by their creator, but, during the review process, by knowledgeable peers. Furthermore, accepting a design paper that contains only preliminary testing does not mean that more formal evaluation is discouraged. Rather, it is an acknowledgement that a truly innovative design is a contribution in and of itself. The assumption is that structured assessment will take place at a later date.

It is important that design contributions not be relegated to special design tracks at conferences. Creating a design or art track will very likely enliven a conference; SIGGRAPH and ACM Multimedia are good examples of conferences that have been enriched by such sessions. But, I believe this step is a backward one in the long run. If conferences create special tracks for design contributions, they decrease the likelihood that design will ever become an accepted or integrated part of computer science research. By confining design to special tracks, the community demotes design, making it very difficult for a design-focused researcher to find a home in a computer science community, in effect “ghettoizing” designers. We need to think about existing paradigms, not institutionalize existing barriers.

How can this transformation take place? Here are some suggestions of small places to start: Paper evaluation procedures could be changed to encourage reviewers to pay more attention to design and “big picture” issues; conferences like ISWC—and others with similarly natural ties to design—could devote one session (still part of the full paper, main conference, track) of each meeting to design; tenure processes could be reexamined to give more weight to “real world” impact. Most importantly, communities need to get together to collectively articulate what design is and why it is important, and to develop comprehensive plans for recognizing design as a central component of technology research.

As the competitors of the iPod have learned, institutions ignore design at their peril. When an academic field doesn’t reward or encourage innovation, it becomes increasingly insulated and irrelevant. Big ideas are abandoned and researchers lose sight of the field’s relationship to the world at large. If the wearable computing community, and ISWC, are to continue to grow and flourish, they must welcome, indeed invite, design contributions.

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Reconciling ICT and Wearable Design: Ten Lessons from Working with Swatch

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Abstract
This paper describes a product development collaboration between Swatch, a wearable design company, and Hewlett Packard (HP), a provider of Information and Communication Technologies (ICT). For both companies, the interaction was unique in that it required them to consider the deployment of wearable computing technology and support services into an application space dominated by fashion design. The author of this paper worked at Hewlett Packard Laboratories, and was extensively involved in this joint work. The goal of the project was to broaden the market for Swatch’s designs by using ICT. However as the project progressed it became clear that the influence of ICT on fashion design is highly complex and reciprocal. This paper describes what was observed during the 3 years of the joint project, and presents ten learned outcomes from the attempt to merge wearable computing with fashion design.

1. Introduction
In the summer of 1999, representatives of Swatch and Hewlett Packard agreed to meet in order to discuss possible new joint business opportunities that would combine Swatch’s wrist-worn design, and HP’s mobile computing and internet service technologies. For members of the Appliance Technology group inside of HP Labs, this seemed like a wonderful opportunity to deploy their sensing and wearable computing technologies into a wristwatch format, which was referred to as the Swatch Web Watch. The initial impression by HP Labs was that here was a way to bring computing to a new form factor. The focus was thought to be a wearable computer as a wristwatch that would offer the features of a PDA plus sensors and wireless connectivity. That it was wrist worn made it reminiscent of the HP-01 LED calculator wristwatch released by HP in 1977.

These initial impressions changed during the first meeting with Swatch, and continued to change over the following 3 years until the joint project ended in the spring of 2002. This paper discusses some of the dynamics involved in deploying wearable ICT with fashion design. In section 2 the differences in product interpretation between the two disciplines are discussed. Section 3 briefly describes the resulting system architecture, which included the Web Watch shown in Figure 1. The intense joint effort between the two companies resulted not only in a successful prototype of the Web Watch system, but also provided a very valuable initial experience for how ICT and fashion design combine and influence each other. This is summarized in Section 4 as ten lessons learned. These learning outcomes should be valuable for both academic and industry researchers in the wearable computing and fashion design fields.

2. Product Perception
Hewlett Packard [1] is a technology centric company offering information technology infrastructure, services, computers for home and business use, and imaging and printing products. When HP Labs was invited to participate in discussions with Swatch, it was assumed that the focus of the joint activity would be a technology design for an advanced wristwatch. A wrist worn wearable computer instantly came to mind that would embody many of the new context aware technologies being developed in the Appliance Technology group at HP Labs, such as sensors for biometrics, location determination, and communication for mobile applications. This thinking was consistent with the product strategy for information appliances that HP sold at the time. From HP’s point of view, devices such as the then envisioned wristwatch, are discrete, physical products. Other good examples of such products are PDAs, calculators and printers where the value is in the hardware, and more importantly, in the specific function of the hardware itself. That is not to say that the appearance of the hardware artifact was not important to HP, and considerable effort was spent in the industrial design of such computing products. However, beyond qualitative marketing references to the relative “geekyness” or the “cool factor” of a product, the focus was primarily on the hardware and its function as defined by physics and engineering.

Swatch Watch is a division of the Swatch Group [2], and is responsible for the marketing, design, and sales of Swatch branded wristwatches. Including Swatch, the Swatch Group has
18 wristwatch brands, and designs jewelry as well, firmly establishing Swatch as a fashion design company. That Swatch has a very different point of view regarding their products became apparent at the first meeting of the two groups in Biel, Switzerland. There, the president and CEO of Swatch gave a short presentation describing his business, which was especially notable for how seldom the word ‘wristwatch’ was used. Clearly they sold wristwatches, but their products were something more that included ‘emotion’, ‘sense of self’ and ‘human interaction’; product terms very different from those that the group from HP was used to. For Swatch, the product focus is not exclusively the watch itself, but includes the physical and emotional enhancement created by the watch for the wearer. These enhancements are factors that contribute to one’s personal and social identities in ways consistent with Social Identity Theory such as defined by Tajfel and Turner [3]. Along with the watch, these personal and social identities, and in turn their influence over an individual’s interaction with others, are Swatch’s product, and are what was meant in the references to emotion, sense of self and human interaction. Swatch was already successful in building products that create this kind of social identity among co-located people. What they wanted was a way to extend this into the internet to include geographically separate groups of Swatch wearers in real, augmented, and virtual spaces. Virtual Swatch wearers were also part of this vision. To get this into the internet space was the reason Swatch proposed to work with HP Labs. The Web Watch by itself, although a central component of this vision, was not the ultimate product. The challenge moving forward was to reconcile these two perceptions of the product.

3. Web Watch System Architecture

The realization of the product vision took place over 3 years in a joint research effort between Swatch and HP Labs. The result was a system architecture consisting of three core components; the Web Watch, a lightweight server infrastructure, and a service framework featuring the ability to support abstract entities. The Web Watch was the first component of the system to be addressed, and underwent the most changes over time reflecting the shift in thinking from a discrete, physical product towards a product that emphasized physical and emotional enhancement. All of the architectures for the watch had common features consisting of a processor and memory, a display, buttons for user input events, and a low bitrate radio for data communication. In 1999, low power 32 bit processor cores with considerable amounts of embedded I/O were available, and Bluetooth radio modules supporting personal area networks were also available in a realistic time frame. These were all known to the wearable computing community, and to design a watch based on these technologies was not in itself very difficult. The real question was what application technology combined with this basic architecture, and put in a wristwatch format, would result in the most compelling product? Answering this question is where the bulk of the collaborative interaction on the Web Watch took place. The significant watch derivations with their intended technical focus to support envisioned applications are shown in Table 1. The ‘Browser Watch’ proposed to embed a Wireless Markup Language (WML) browser into the basic architecture, with the idea that the user would pull web content onto the watch for viewing. This thinking was influenced by similar thought taking place in the cellular handset industry which was also looking at supporting the Wireless Application Protocol (WAP) and WML. The poor user uptake rate of the early WAP phones, combined with the need to transcode or reconstruct web content for small displays made the Browser Watch proposal seem not viable. This led to the second iteration called the ‘Java Watch’ which added to the processor core a hardware Java virtual machine. This was a major step in the right direction, because it represented a focus away from the hardware of the watch, and towards applications. The use of network downloadable applications exploiting Java technology was becoming a great success on desktop PCs, and road maps existed to extend this technology to mobile devices. The idea of downloading applications onto the watch was very appealing to Swatch, and started a large number of ideas for applications promoting human socialization and for personalization. This led to the third iteration of the watch called the ‘Chai Watch’, which used a software Java virtual machine that was offered as a product by Hewlett Packard at the time. The HP Chai virtual machine had the advantage that it was engineered for web based applications, but despite its advanced features, it was beyond the constrained resources of the watch hardware. The interest in personalization drove a context aware fourth iteration of the watch called ‘Watch PAD’. This version added an active pixel image sensor, and a sensor in the watch band that would detect if the watch was being worn. The active pixel sensor was thought to be useful to determine if the user was looking at the watch, or to detect user motion.

The Web Watch that was ultimately prototyped used none of the technical focus features from the four iterations. A functional block diagram of the prototype Web Watch is shown in Figure 2. Discussions about application support for the watch brought out that communication between users was the most important aspect of any application. All media types such as text, images and video were important, and could be real time or time shifted depending on the impression the user wanted to create, or the space in which the watch was being used. Because of this, PDA like features were not seen to be important, nor was there seen a need for the user to program the watch with their own applications. Sensors for context detection that could be used to personalize applications, or to allow the watch to perform advanced transactions on the user’s behalf were seen as having very high potential, and were deferred for later development.

The Web Watch diagrammed in Figure 2 was able to perform peer to peer communication among users. This provided a mechanism for information exchange, but by itself was not sufficient to provide the internet located social context into which users could project their enhanced personal and social identities, or allow these identities to influence how the users interact with each other. Although the Web Watch from an ICT viewpoint was

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<th>Proposed Watch</th>
<th>Processor</th>
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<td>Browser Watch</td>
<td>8 bit core</td>
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<td>Java Watch</td>
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Table 1: Proposed watch derivations
The collaboration between HP Labs and Swatch brought together a unique combination of ICT and design cultures. What started out as a wearable computer project focused on a discrete, physical product, from a design viewpoint it still fell short. To complete the product, two more components were added. The first was a small, low cost “HotSpot” server [4] that performed both application hosting and mediated communication services for the Web Watch. The second was a unique service framework called the Web Presence Manager (WPM) [5]. The relationship of all system components is shown in Figure 3.

The HotSpot server was primarily responsible for providing mediated communication services for the watch, especially access point services to bridge watch connectivity to the internet. It also provided other services for the watch such as authentication, rule based customization of applications, media transcoding and rendering, and media download and storage. The media services were especially important because although the watch could display images and video, it did not have enough resources to support significant amounts of storage, rendering or transcoding of video. The HotSpot server was physically small and thought to be cheap enough that cost would not be an obstacle to its deployment in relatively large numbers. The HotSpot server could also host the Web Presence Manager.

The Web Presence Manager served as a container for the identities that users placed into the network and as an engine to associate these identities with events, actions, and context such as location, time or other web presences. It is the WPM, in conjunction with applications using the data it maintains, that gives the user’s personal and social identities an existence in internet space, and provides the context which allows them to have social meaning. Any real or imaginary entity such as a person, a room, or an abstract object such as media can have an on-line web presence, and be represented by the WPM.

Figure 2: Swatch Web Watch Functional Block Diagram

Figure 3: Web Watches with HotSpot and WPM components

Entities in the WPM are represented by XML descriptions, and are managed by functional modules that make up the WPM. Some of the more important modules are diagramed in Figure 4. The Description module maintains information that describes the entity. In the Web Watch case, that would be the chosen identity of the wearer along with any other data the wearer would like to reveal. The Directory module manages the relationship of an entity with other entities that have a web presence. In this case it could be groups of other Web Watch wearers, meaningful locations and other things that add to the overall space being managed. These relationships can be temporary, or more permanent depending on an application’s needs. The Autobiographer module maintains an event log for the entity. It can record anything that happens to the web present entity, for example a change of location, or input from a sensor, and make this information available to applications. These events can also include actions being performed by another web presence, such as the playing of a MP3 audio file. The Observer module keeps a set of rules and actions that can be executed within a web presence, for example in response to an event recorded by the Autobiographer. Such a response can include external actions, such as sending an email, or playing media. The Listkeeper maintains a history of the context of the entity, usually derived from the Autobiographer and Observer modules. For the Web Watch wearer, it could maintain a list of what other Web Watch wearers, real or imaginary, were in a space at some time, who arrived late or left early and with whom, and what other events, such as listening to music or sharing images, took place. This information can be indexed, grouped, and provided to applications by the Indexer module. For a Web Watch wearer entering a space, the Indexer could provide information about the previous time the wearer was in the space, including who else was there, and what was happening. Note that, in a virtual sense, this can be used to return a Web Watch wearer to a space they were previously in, complete with representations of the other web presences that were there at the time.

The aggregate of the Web Watch, HotSpot and Web Presence Manager created the networked environment where the personal and social identities of a Web Watch wearer can have meaning and social weight in a very broad sense. Consistent with fashion design, these identities, and the emotion, sense of self, and human interaction that they convey, were able to be represented both in the physical and in the internet worlds as Swatch wanted to do. This comes much closer to the realization of the design product that Swatch had in mind, and far better than the Web Watch as a wearable computer alone could have done.

4. Ten Lessons Learned

The collaboration between HP Labs and Swatch brought together a unique combination of ICT and design cultures. What
computing device ended as a very relevant application of ICT to fashion design focused on social interaction. From the computer science perspective, this experience provided entirely new ways of looking at the role of ICT applied to design, which for HP Labs was an unfamiliar product space. The following is a list of ten lessons that summarize the most important points learned by the group from HP Labs from the interaction, and the impact these points had on the computer science related activities. They have been very useful as guidelines in later technology research.

4.1 Technology and product breadth
Design products are often not discrete, physical entities. ICT applied to design needs to address how it will broaden the context in which the design is used or worn. In the Swatch case, the value of the Web Watch was not that it could browse the internet, or even tell time. The value was that it provided a method to conduct transactions that would broaden the social context the wearers were in to include the internet. The manifestation of this lesson is that it completely changed the design of the watch from a PDA like device to something unique.

4.2 User’s interpretation of ICT and design
From the wearers’ point of view, the fact that the Web Watch was an ICT device was not relevant or important. The challenge is to realize this up front, and then work to determine what the device really means to the users. In the Web Watch case, the meaning of the device is as a fashion vehicle that allows the user to express aspects of their persona into both the physical and network enhanced worlds. The expression is dynamic, and able to interact and change. The realization of this prompted the deployment of the Web Presence Manager to allow the focus of the social interaction to completely revolve around the wearers of the watches, and not on the watch itself. The Web Watch works in part by invisibly conducting meaningful transactions on behalf of the user and the user’s web presence.

4.3 Market expectations of ICT and design
It is important to look for differences in the collaborator’s market expectations early in the project as it can help clarify advantages and risks. In the Web Watch case, when early in the effort the watch was viewed as a discrete product, questions came up if the market would accept a lot of new technology, such as tiny color displays, sensors and personal area networks. The introduction of such a product looked like it would follow a “push model” characterized by a design team starting with new technology, and then hoping to find an appropriate market to push it into. Although the HP Labs team was comfortable with this approach, it is very likely that the Swatch team was not, as their view of the product was not technology centric, and their market model for Swatch watches was very well defined. Later on in the collaboration when it became clear that the users’ interpretation was less about computing, and more about social interaction, the product shifted to follow a market “pull model” instead. This approach is characterized by a design team selecting appropriate technology to meet expressed customer needs. This resulted in less effort put into an ultimate design for the Web Watch, and more effort on how to combine the watch with the HotSpot and Web Presence Manager to provide what the market wanted. Without this insight from working with Swatch, a watch might have been designed that, although technically advanced, satisfied no fashion design market need.

4.4 Customers and demographics
A significant advantage from working with Swatch was that it clarified to the HP Labs team a market which they knew very little about. In HP Labs’ case, the lesson was about youth and young adult customers, and how they relate to design products. This customer segment, along with personal enhancement and social interaction as a collection of customer needs and wants, were not recognized marketing considerations to HP Labs, and so were rarely factors in developing the functionality of ICT products. Wearable computing researchers should use opportunities for working with design researchers to understand their views of people and society in order to broaden their own model of user demographics. If the researchers are based inside a company, this data should be used to challenge existing marketing models. Design researchers should be encouraged to submit publications to the computing community describing how their demographic models are changing.

4.5 Influence of applications on design
The Web Watch as a product could only exist inside of an application system. The framework for this was provided by the HotSpot server and the Web Presence Manager, and with the Web Watches formed the basis for the application system. System engineering of this kind was new to Swatch, and it was necessary to spend time educating Swatch designers about the overall architecture. Without it, Swatch would have had a hard time constructing realistic Web Watch use scenarios, and they would have been limited in their appreciation of the value the ICT brought to the product. The point here is that ICT engineers need to work with designers to fully develop the system view in which the product will be used. In addition to presentations and web training sessions, a prototype and demo application running on the system are very useful to communicate the system vision.

4.6 Prototype
The joint creation of a functional, in form factor prototype was essential. Without such an activity both teams would have had a much harder time communicating, understanding, and optimizing ideas and solutions. The prototype kept both teams working coherently. Also without it, the participation of executives with budgetary and decision making powers would have been lost at an early phase. The skill sets exhibited by the joint participants were orthogonal, and included everything from fashion design, and watch making, to computer design and web programming. Simulations and computer models, although useful, were not sufficient in the collaboration as they did not represent a common tool set across both engineers and fashion designers, and had little meaning outside of the technical groups. Universities should teach physical prototyping skills in laboratory classes. Researchers skilled in creating prototypes should offer tutorials or web material describing their methods.

4.7 Personalization extended to humans
Personalization as a component of context aware computing is usually thought to apply to inanimate ICT artifacts including the spaces in which they are used. This makes sense in situations where ease of use or aesthetics is an issue and personalizing the device or space to suit the user is a good engineering goal. In the case of design and the Web Watch, the device is instead used to personalize the user to express a particular aspect of emotion or sense of self. This is distinct from representation and the use of avatars. The challenge here is to apply the ideas of personalization to real humans. Using data gathered by the Web
Watch and managed by the Web Presence Manager was an important start, but more work needs to be done on how to personalize a real identity that has been projected into a networked space. Modern internet social networks may uncover a lot of information on how to do this.

4.8 Design’s impact on ICT engineering

The needs of design have a significant impact on ICT engineering in unexpected ways. The Web Watch had many unique features that were a reflection of Swatch’s product knowledge that were new to HP. Examples include the need for no holes in the watch case to keep the insides perfectly clean and dry. In the case of many Swatch branded watches, battery life is expected to be at least 5 years, or about the same expected use life of the watch. For the Web Watch, this meant that any interaction with the inside hardware of the watch, including charging the battery, had to be done wirelessly. The Web Watch’s battery was inductively charged by placing the Watch in an attractive illuminated charging stand. The user interface had almost no buttons, reflecting that a watch was not so much about explicit user input, as it was about the user consuming information the watch provides. Display update rate and compression support for video was more important than image quality and display resolution. The fact that the watch is worn on the wrist is also an important point for Swatch, which they made clear when they stated that they ‘own the wrist’. The wrist is an interesting body point for worn design in that it has a public, outward facing side as well as a private, or inward facing side. All these factors can result in very interesting engineering ideas for product hardware and applications.

4.9 ICT’s impact on Design

The capabilities of ICT will in turn have a significant impact on the thinking of fashion designers. The ability of both the HP and Swatch groups to astonish each other in turn boosted the creativity of both groups. In the Web Watch case, the fashion designers at Swatch initially had no idea of the capabilities the watch could have. This in turn caused them to look at a number of new ways that users could interact, and come up with scenarios where many aspects of popular culture and activities were given web presences. Web presences were even considered for Swatch retail outlets. The realization of the role of ICT in fashion design may also have been a contributor to Swatch’s decision to form an internal internet research group originally located in Morges, Switzerland.

4.10 Research Questions

The Web Watch project combining ICT engineering with the fashion design process uncovered a number of research questions. One outcome of the collaboration was a realization that current processes and metrics are not sufficient to articulate fashion design requirements or measure results. From this, the following research questions are proposed:

- A theory of societal factors in ICT and service design.
- Models for observation and data collection.
- Formulation of data types used to express societal factors with respect to ICT.
- A system of metrics to evaluate products that combine ICT and fashion design, and to express value.

These represent an opportunity to provide research contributions in both the design and ICT related fields.

5. Discussion and Conclusions

Why some ICT and design integration projects succeed while many others fail is not well understood, and is often assigned to a combination of serendipity and “getting the market right”, neither of which are satisfying from an academic nor economic point of view. The ten lessons outlined from the Web Watch project were the results of a first serious attempt by the groups from HP Labs and Swatch to create a fashion design product heavily enhanced by ICT, and to understand how ICT and design influence each other to result in successful products. The collaboration concluded with a complete technology demonstrator that encouraged both companies to move forward towards further development. However, neither the Web Watch nor the system architecture components became commercial products after the collaboration ended. The reason was that neither company realized until after the study was complete that in addition to a new product, an entirely new business in on-line fashion and social interaction had been invented as well. On the one hand, this was very encouraging evidence that the combination of ICT and design can yield results that are unique, successful, and much bigger than the sum of the parts. On the other hand, neither company was prepared to take on the risks of a new business. Swatch pointed out that at the least, a new brand would need to be created and launched at the cost of millions of Swiss francs, which would have far exceeded the development cost of the Web Watch itself. Rather than being viewed as a negative result, this instead demonstrates the large potential opportunities from the successful integration of ICT and design, and the importance in understanding how to make such co-design efforts work. This work also demonstrated the drivers that societal factors create in design and how ICT can be used to satisfy the wants created by these drivers. Many of these factors are emerging again in the form of new internet social network services. All of this justifies further work in understanding how fashion design and computer science can learn from and influence each other.

6. Acknowledgements

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7. REFERENCES


Natural Language, Connectors and Fraying Threads

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Natural Language – Connectors – Expectations – Process- Communication – Content – New Models

"I defy anyone to design a hat, coat or dress that hasn't been done before...The only new frontier left in fashion is the finding of new materials." Paco Rabanne, 1966

I have been working with wearable technologies for the past 10 years and during that time I have collaborated in various projects with fashion designers, cobblers, electrical engineers and pattern makers.

I have often talked of the difficulties of bridging the world of fashion and technology and their respective methodology, process, approach and production life-cycles.

In the past 6 months I have been working in my studio full time with a fashion assistant and an electrical engineer as we are building a collection of 8 interactive garments. It is the first time that we are working on a collection that we plan to sell commercially – most of the projects so far were prototypes that investigated possible technical approaches and solutions as well as exploring the expressive possibilities of technology.

The experience has proven to be both humbling and incredibly exciting; it has also elucidated all the challenges and difficulties inherent in the process of creating a new area of practice. I say a new practice, because after struggling to fit the fashion world into the engineering one and vice versa, it has become clear that what we are working on belongs to neither of these fields, but instead belongs to a new area that balances between design, technology, art, fashion and anthropology.

By opening up a new space and exploring this new crevice we come to realize that it offers new possibilities in its own right and that we have to forge a new approach. In doing so we have better chances of creating both commercial and experimental successes.

Working side by side for six months with an electrical engineer and a fashion assistant it was fascinating to see how each practitioner is entrenched in their own language – how difficult it has been for the two to communicate and enter the other’s domain and operating mode. I am not talking about technical knowledge, but instead of “attitude”, that un-fixed term that is critical in close collaborations. Language, what we think we say and how the other perceives it has been one of the main obstacles in promoting and realizing wearable technologies. It sounds like such a small issue on which to declare
defeat, but what it really means is that it is important to engage in the design process with as few preconceptions or assumptions as possible.

It also means that it is critical to have a parallel development and close collaboration between the interaction design, fashion design and engineering process. Mapping the design goals of the project separately from the engineering process can only result in a series of compromises or extreme frustration on both sides.

A change in the size of a battery board meant that the pattern for the pocket that housed that board had to be changed. What seemed to the engineer to be a small, insignificant change, and one that maybe would not be immediately communicated, had greater implications for the pattern and the overall construction of a garment.

Similarly, there were times when the fashion designer would get frustrated for failing to understand how switches work, or how the power and ground threaded paths should not touch and wiring paths would be erroneously marked on the patterns.

Overall, the greatest challenge was trying to keep the two schedules run in parallel, so prototyping in one area was reflected in the other. That is not always possible due to the nature of the turn-around in each area. While circuit boards need to be sent out, shipped back and populated, it is much faster to prototype an idea in muslin. Since we have 8 projects running at the same time it was easier for us to shift not just between practices but also between processes and try to have most of the engineering solutions apply to all garments.

In hindsight it seems that some of the miscommunication was a result of a certain kind of intimidation from each side – the engineer feeling intimated in not understanding the design/patterning/cutting process and reversely the designer not understanding the engineering one. A week-long workshop where each teaches the other their skills and process would have resulted in a better appreciation of each other’s contribution and is certainly where each new project will now begin for us.

It is clear that the design goals must be discussed at their inception and the design and engineering tracks must run in parallel. Aesthetic considerations are a part of the engineering process while hardware and software requirements must be folded into the design seamlessly and not as an after thought.

When the two creative processes are smoothly informing each other creative solutions are born of that interchange. Mapping out the wiring possibilities, interconnects and power management are necessarily a combined effort, and we found that in the process design keeps pushing the boundaries of engineering and engineering points to new possibilities in design.

Building a new model for the process is critical and it involves an educational plan and a basic understanding of each other’s work.

Apart from communication, a bridge that can be built, the most pressing issue in the development of wearable technologies is the lack of adequate connectors and accessible tools. While engineering and computer science departments develop complex and
sophisticated wearable systems, there are few tools available for the design practitioner (fashion or interaction) to quickly prototype new ideas and test their behavior.

With new platforms such as the Arduino and Leah Buechley’s ground-breaking work with textile based took-kits there is much promise.

At our studio we have been trying to create our own standardization process, building most of our boards to follow the same form factor (size, connecting options) and to keep those as flexible as possible. We have also been building what we call the “Golden Fleece”, a wearable bread board of sorts that we hope will help us build a library of hardware and software that we can easily re-purpose for new projects. We have developed a fabric pattern made of conductive threads that allow us to attach our boards anywhere on that surface.
Battery Board with magnets

Back of “Wearable Breadboard” with conductive threads for power, ground and data line.
Still, lack of adequate connectors between conductive threads that have the tendency to fray, and attractive connectors for removable, rechargeable batteries, make the development process so much more time consuming and frustrating. It also makes it harder for the unseasoned practitioner to innovate and focus on the aesthetics and “content” of the work. At this stage we have experimented with all sorts of connectors: magnets for our custom made battery boards, snaps, pins, sam browne buttons… we have tried it all and we have yet to come up with a satisfying solution and one that would make manufacturing easy. At this point our garment construction is more akin to couture than to ready-to-wear.

When we have the right tools and connectors will wearable technologies take off? Do we have the right framework in order to think of wearable + technology?

Even though I often use the term “wearable technologies” to talk of the work we do, I find the term misleading and guilty of a type of future tense anachronism. The entire history of textiles and garment construction is about technology, innovation and experimentation.

It is important to keep this in mind as well as understand what drives human beings to “dress”, what are the narratives, intentions and projections that are weaved in our garments. This element, the “content” of the interaction, is as important as all the technical challenges put together.

In our collection we make distinct references to early garment construction techniques and reference in subtle ways the historical transmutations of garments, with electronics being only one of the steps. We approach electronics as just the most recent innovation in a long line of innovations and examples of an incredible humanity that resides and is exemplified in our garments.
Masai Dress (as the brass beads of the collar touch the conductive threads on the dress various sounds are generated)

The challenges of this incorporation are many but the gap is slowly closing – the only way we have found to successfully diminish it is by constant iteration in all 3 parts: electronic design, garment design and software design, but always, most importantly human design – or design for humans (history, culture, notions of self, concept – narrative and meaning)

If iteration is a fundamental part of our process, collaboration is essential – collaboration amongst the Studio’s team but also collaboration with our colleagues in other companies or research institutions, with companies that develop new materials and are eager to help us find ways to use them successfully, and with the larger community.

We believe that in order for electronic garments to gain successful entry into the marketplace we need to work together as a community and share our insights and solutions.
At the same time we need to collectively raise a series of questions regarding pressing issues in wearable technologies – from content to manufacturability, their assimilation and “function” in social environments and availability of tools and techniques to design practitioners.

Exploration of new materials and techniques that users with little experience in electronics and programming can readily adopt and adapt, the prototyping of serendipitous and whimsical devices that have social and emotional affordances rather than focus on functionality, and an open and inspired dialogue between the design and engineering community might be the first steps toward the construction of compelling wearable technologies.

In creating new devices and techniques we also develop new relationships and new practices. Each artifact carries its own ideology and in creating new artifacts we also create new ideologies.