# MOVING SOFTLY FORWARD

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This paper identifies themes in wearable technology practices within the context of research in universities and art and design schools as well as industrial laboratories to suggest opportunities for concentration of efforts and international collaboration. Research using biometric data, heart rate monitors, embedded sensors, blue tooth and mobile networks, conductive threads, soft circuitry, smart textiles and shape metals and other adaptive fabrics occur at sites in around the world. Where are these? Secondly, the paper begins to map these research efforts to the potential of take-up by adopters (fashion designers, healthcare, and security services as examples). Finally it suggests some opportunities for collaboration and points to strategies needed to bridge the gap between research or art and design prototyping and large-scale adoption.

## INTRODUCTION

This paper reminds us of critical and technological concerns that were appropriate to an earlier phase of fashion and technology research. It then checks these against research in universities and art and design schools as well as industrial laboratories to suggest the breadth of current research. The paper begins to map these research efforts to take-up by adopters (primarily fashion designers) and then suggests some pointers to bridging the gap between research-based art and design prototyping and large-scale adoption.

## 1. WEARABLE TECHNOLOGY, FASHION AND ART RESEARCH - 2003-5

The *Wear: Smart Clothes, Fashionable Technologies* July-August Issue 16 of Horizonzero.ca identified the rising interest in wearable technologies:

Summer 2004's most glamorous fashions are about looking "intelligent", "adorable", and "well connected". Digital is the "it" colour this year, and clothing designers are hitting the runway with e-ink, electric plaid, soft plasma displays, barometric fibres, conductive threads and wireless chic. That's why *HorizonZero* has been combing fashion houses and tech labs around the globe in order to bring you the very latest technology-laced textiles and accessories. [1]

*Wear* argued that technological change in the form of smart textiles, new flexible materials and protective surfaces was allowing us to "protect and personalize" [2] our bodies in new ways, offering us a "second skin". At the same time the issue acknowledged the transformative impacts that mobile devices, whether a phone or mp3 player were manifesting on social and economic life.

function of garments? I noted, "The technologies that we deploy - digital (carrying and communicating from signals), material (inks, threads), biometrics (measuring and responding to our biological rhythms), nanotechnological (transforming with the chemical nature of our bodies) - are all temporal media". [3]

These qualities were relevant in relation to "something uncanny but tremulously exciting in the possibility that our clothes, our jewelry, our ornaments might speak for us - and with others - in explicit ways, and as intuitive, quasi-independent systems". I proposed the notion of "endogeny",

…the potential of internal, evolutionary, and adaptive change in these materials and their expressions For example, can we make ecologically viable garments that change their form, their fabric and expression, and allow for an economy of reprogramming rather than one based on the constant consumption of new objects? How can we combine endogeny with exogeny, the creation of new interfaces that communicate with and between systems?[4]

In my editorial I posed a series of provocations to fashion and technology. First of all, were we able to understand and mobilize the individual and social temporal, event and memory-making

Further, there was the question of how might form and function not only serve elites but, "fit the needs of the majority (in terms of durability, affordability, cultural specificity, and beauty for example) rather than only the wealthy?" These questions retain their relevance in 2011.

In an examination of trends in 2004 Joanna Berzowska [5] divided practices and emerging tendencies into three fields – 1) **wearable computing** where individuals wear computers on their bodies, either as routine **mobile** technologies that are responsive to context and place or as cyborg technologies, primarily **headmounted** displays. 2) electronic textiles, "a knit or woven substrate that incorporates capabilities for sensing, communication, and power transmission, as well as interconnection technology that allows sensors or processors to be networked together within a fabric." [6] These materials offer the ability to change colour, adapting to landscape or personal contexts. A second set of applications use sensor arrays and embedded sensor technologies from biosensors, to environmental sensors, to audio, movement and pressure sensors. These can be "directed inward or outward;" [7] 3) **universal connectivity, using biofeedback, network, and monitoring technologies such as RFID**. These technologies can be used for medical compliance and safety monitoring and intervention. Berzowska asks, "What kind of information processing do we want to carry out on our bodies? What kind of functionality do we want to enable inside our clothes?" [8] She raised concerns that too much attention is being given to surveillance and monitoring, not personal expression.

To imagine the year 2015 the issue commissioned "windows". Maggie Orth's "Weather Jacket" raincoat could predict the weather and change qualities in response to it. It was cinched by a "Destination Belt" embedded with GPS that could guide the wearer through the urban landscape. Sabine Seymour's "Rescue" was a rugged thermal and water proof sailing garment system that would connect the wearer to their boat's GPS and emergency systems, while containing a hidden inflatable life preserver and an emergency beacon. Susan Jenkyn-Jones' "e-scapaid" was a brooch like device that would be recognizable by others and would transmit the wearer's dating preferences. Her kit included a smart dating card that could be left behind embedded with gaming
clues about the wearer. Victoria Lawton's "Nocturnal Dialysis Nightware" used soft tubing embedded in a nightgown, electronics and micro technology to deliver dialysis while the wearer slept. In reviewing research and commercialization efforts in 2011 these projections are reflected in fashion, medical and security systems research.

## 2. CURRENT RESEARCH

Research capacity has expanded in the three fields that Joanna Berzowska noted in 2004: wearable computing (mobile, head mounted); electronic textiles and universal connectivity, using biofeedback, network, and monitoring technologies such as RFID. An online search by this researcher exhumes significant references and suggests that wearable computing has moved into the mainstream and has had significant take-up within biomedical engineering. Valerie LaMontagne's survey web site http://www.valerielamontagne.com/wearables.html allows the reader to gain a sense of the breadth of wearable research and design particularly in Europe and North America. The blog http://www.electricfoxy.com/ provides regular updates on events, topics and people in the field. Sabine Seymour's two volumes [9] scope out art and design wearable technology practices and Bradley Quinn [10] describes emerging trends in textile research, such as new tensile materials comprised of nano fibers.

Research fields have grown exponentially, whether fitness, biomedical monitoring or security applications. Mobile devices, wifi, Bluetooth and related network technologies have become ubiquitous in the last seven years, stimulating a return to interest in the integration of mobile networks and devices into worn devices or garments. Inexpensive microcontroller systems such as the washable Lilypad Arduino or affordable LED systems have seen the growth of craft and DIY (do-it-yourself) applications. New materials such as shape metals have provided new opportunities for responsive fashion and accessories. Malleable voltaics support aesthetic and functional energy systems. Significant advances have occurred in textile research thanks in part to space agency and military efforts. The Cleoxa company blog notes, "We find materials that are highly resistant to abrasion, or extremely insulating…but the most impressive is the memory foam membrane, according to outside temperature, the molecular structure of the fabric changes." [11] Projects such as Future Force Warrior System (USA) combine bullet protection (textiles) with communication device integration (sensor, networks, monitoring). A notable area of expanded interdisciplinary collaboration is the field of health technology and design. For example Swedish student designer Marjan Kooshnia has created medical masks that, "give an aesthetic warning if the wearer is running a fever or the concentration of allergens in the air exceeds a certain threshold. The pattern printed with thermo-chromic ink changes color when the exhale exceeds 27'C." [12]

University research laboratories or networks amalgamating engineering capacity with wearable art, design and fashion and domain expertise (such as biomedical) now span a growing number of continents and countries. The recognized need for intensive cooperation between varied technological and design research is one of the critical turning points of this decade. Design is acknowledged for its aesthetic, form-finding and usability roles. Research into the components of wearable technology has also expanded. For example European intelligent textile research has grown through a focus on defense, medical and sports applications. In Germany there is the Fraunhofer Institute IZM and Stella: STretchable ELectronics for Large Area Applications, Berlin; in Belgium University of Ghent; in Sweden Chalmers University of Technology, Swerea IVF and the University College of Borås, Textile Department with a Northern European aggregate, NICE, the Nordic Initiative, Clean and Ethical - Fashion. The Smart Textile Network links Swedish researchers with businesses such as H&M Rowells, Eton, Ludvig Svensson, Borås Wäfveri, Sanden textiles and Kasthall in Sjuhärad, the Scandinavian center of textile, mail-order and e-business. Products vary from clinical medical use, to sound absorption, to fashion applications. Belgium is a contributor to smart textiles research. Projects by students at the University of Ghent suggest a breadth of investigations such as, "A self-heating sweater; a textile antenna; Are you still breathing? Measure your heartbeat." [13] Industry research has rekindled with Philips is leading research in developing light emitting textile substrates which can be washed.

Capacity in the UK exists at numerous institutions including the Universities of Nottingham and Bristol, Central Saint Martins and London School of Fashion, Distance Lab, Scotland. The University of the Arts London Textiles Futures Research Centre encompasses its four art and design colleges. Its mandate is to "undertake a clearly focused range of textile related research that facilitates technology translation and convergence, improving the interface between science and design, the exploration of sustainability, the expansion of the textile product/applications, and the redefinition of cultural and aesthetic norms". The London School of Fashion has created the Centre for Fashion Science with research in Responsive and Multifunctional Textiles. Textile Futures Central Saint Martins, "share a practice-led approach through which to pioneer new hybrid methodologies, harnessing computers, lasers and electronics along with emergent bio and nanotechnologies. With sustainability and a sophisticated aesthetic as a common thread, the members' diverse research expertise addresses the future fabric of life by engaging with fashion, interiors, food, biomedicine, the built environment and evolving social interactions" [14] The United Kingdom is home to several focused Masters degrees in wearable technology, for example The University of Wales, Newport, M.A. or M.F.A in Smart Clothes and Wearable Technologies. [15] All of these programs place ?sustainability? in a critical location – an issue that was barely considered in the emerging years of fashion and technology research.

The European Union Framework grants have provided opportunities for large networks the bind together applications and component (substrates, electronics, fabrics) research. The SYSTEX Coordination Action for Enhancing the Breakthrough of Intelligent Textile Systems (E-Textiles and Wearable Microsystems) [16] addresses the medical, transport, protective, sports and wellness markets. Researchers have found ways to apply conductive textile yarns to create intelligent textile systems; others have integrated a heart monitor into a stretchy garment, thus affording it adequate contact with the skin. The EU PLACE-it: Platform for Large Area Conformable Electronics by InTegration identifies barriers in interdisciplinary knowledge by building bridges with industry. SERVIVE led by the London College of Fashion investigates virtual worlds as a location for fashion ecommerce.

Canada has retained and built its research capacity in wearable technologies. Kate Hartman’s Social Body Lab at OCAD University in Toronto links social awareness, art and design with a wide expanse of technologies, "Beyond the basic functionality of incorporating technology into clothing, the Social Body Lab focuses on meaningful and provocative interactions, questioning the relationship between humans and technology through working prototypes and fully manifested projects." [17] Hexagram in Montreal includes Ying Gau a researcher at the UQAM in fashion and new media, and a concentration from Concordia University: Joanna Berzowska, Barbara Layne and Ingrid Bachman. American engineering, nanotechnology and design programs include MIT, Georgia Institute of Technology (USA), Virginia Tech (USA), Carnegie Mellon (USA), Parsons School of Design (USA), the Interactive Telecommunications Program, NYU and Stanford University. Research has grown in Japan (University of Osaka for example has a focus on user-driven design), Brazil (Anhembi Morumbi University) and there are emerging centres in Australia (University of South Australia), Hong Kong and India (Institute of Apparel Management). Hong Kong Polytechnic’s Institute of Textiles and Clothing addresses electrical, textile and biomedical engineers as well as academics and fashion designers. They state, ?Integrating electronics into clothing is a major new concept, which opens up a whole array of multifunctional, wearable electro-textiles for sensing/monitoring body functions, delivering communication facilities, data transfer, individual environment control, and many other applications. [18] The IAM is interested in the ways that intelligent textile manufacturing can be introduced into traditional fabric production methods as well as fashion applications.

Another significant change spurred on by advances in miniaturization and the accessibility of Arduino and other consumer electronics is the growth of a dynamic DIY culture. Electronic crafts have arrived at the foreground of wearable practice. For example Syuzi Pakhchyan's SparkLab "is a body of DIY projects that investigate between culture, technology and craft. It encourages a new methodology for assembling electronic circuitry which merges sewing techniques with electronics. Wires are substituted for conductive thread, snaps for solder joints and connection points, and everyday silk organza is used as the conductive medium." [19] She provides users and consumers with the tools, patterns and materials to create their own electronic jewelry.

There has been an exponential growth of artists' based research, providing a critical and alternate gaze at the growing trend towards monitoring systems that underlies much technical and commercial research into wearable technology. As electronics is standardized some artists have moved to new technology edges, for instance linking brain wave monitors or using electrochemical sensors to measure changes in sweat.1 behavior. New media art centres now consistently host artists' projects in wearable technology. These include the V2_Institute for the Unstable Media (Netherlands), Eyebeam (New York), and the Banff New Media Institute (Canada). [20]

Concerns about the social impacts of wearable technologies that were expressed in*Horizonzero.ca* 2004 are echoed in the premise of laboratories such as those at OCAD University, Hexagram and the University of the Arts London. Unlike 2004, research projects in universities and industry are now explicitly focused on issues of sustainability and environmental impacts, concerns that were raised but not addressed during the early rise of wearable technology. Research concentrates on lowering power consumption as well as inventing new power sources such as solar or piezo electronics – energy harvested from human movement, thermal harvesting, solar cells and printable batteries. Helen Story is the co-director of the Centre for Fashion/Science at the London College of Fashion. She creates fashion art works meant to provoke environmental awareness such as Catalytic Clothing that cleans the air around it with purifying filters. Elena Corchero has developed a sun umbrella and other vibrant accessories that refuel each day with elegant photovoltaic panels expressing a pattern at night. Ying Gau of UQAM states, "Le thème central de mon travail est l'environnement, qu'il soit social, climatique ou urbain…je travaille sur la problématique du vêtement en tant qu'objet de médiation entre l'homme et son environnement physique et social." [21] Discursive forums such as the May, 2011 Wearable Technologies: Cross-disciplinary Ventures on –empyre soft-skinned space investigate the growing presence and integration of wearable technologies in media, military and fashion wear and the impact of these trends on how the body is represented, controlled and understood. Some of these concerns have filtered into commercial fashion and technology. We are still far away from the integration of "endogeny with exogeny" of recyclable and sustainable fashion.

## 3. DISSEMINATION AND ADOPTION

Seven years later the fashion industry is integrating wearable technologies, often using tools that were previously in prototype phase and are now more resilient. Fashion offerings revisit projects that artists and adventurist designers once sketched or prototyped. Take-up has grown in the fashion industry. While labour intensive to make and hence limited in reproducibility the couture demonstration projects have an aesthetic depth. When Lincoln Phillip searched for fashion industry interest in wearable technologies in 2004 he only found works by artists and designers on the edge of industry. This year the digital media content showcase South by South West in Austin, Texas included a wearable technology show. The 2011 Consumer Electronics Show in Las Vegas presented FashionWare. The runway featured mobile

enabled applications, LED systems and thermochromic inks. Designers, many of whom graduated from Parsons School of Design, MIT Media Lab, London College of Fashion, Central Saint Martins, were Connor Dickie, [22] Diana Eng, [23] Becky Stern, [24] Fang-Yu Lin, [25] Alison Lewis [26] and Amanda Parkes. [27] Their work brings us back to concepts presented in Wear! Horizonzero.ca as well as earlier works referenced on http://www.valerielamontagne.com/wearables.html.

In 2011 the blog *ChipChick – Technology and Gadgets from a Girl's Perspective* proposed "Ten High Tech Fashion Designers to Watch". Zara Rabinovich elegized about the Rainbow Winters [28] line by UK designer Amy Konstanze Mercedes who uses "thermochromic and hydrochromic ink which alter in rain or sun, providing stunning visual effects, such as appearing and disappearing flowers and patterns" [29] drawing on a background of costume design for theatre. Anastasia Radevich's [30] sculpted shoes diffuse light through fibre optics, activated by a switch at their ankle. Vega Zaishi Wang [31] applies electroluminescent lights to chiffon to sculpt out patterns that are revealed through the soft fabric. Slvr Lining [32] uses subtly placed solar panels in everyday wear to recharge mobile technology. Cute Circuit [33] is a London company that creates couture designs – at times for celebrities such as singer Katy Perry whose white dress flickered with pink LED lights to the beat of song with Kanye West. Her dress glowed and lit up when she moved. Several designers—Francesca Rosella of Cute Circuit and Diana Eng have spent significant time within the couture and ready wear worlds and their facility suggests a new sophistication as tested concepts are injected with strong design aesthetics.

## 4. SOME IDEAS ON COLLABORATION AND ADOPTION

There is clearly movement in the commercialization of smart textiles, wearable mobile technologies and wearable sensor systems, although analysts note that since the 2008 economic crisis ?large investments in intelligent textile products have mostly been among well consolidated brands; Nike, Adidas and Polar in sportswear and Viking Lifesaving equipment in PPE. [34] Consumer sports products such as integrated music devices and heated garments have grown. [35] Commercialization opportunities in the larger field target specialist markets - work wear, personal protective equipment and safety, with slower take-up in healthcare monitoring, in part because of privacy concerns. This latter field will grow with the rise of telemedicine, advanced applications in pharmaceuticals and the needs of aging populations who require in-home care and self-monitoring technologies. Intrusions into the fashion world are still minimal but there is persistence in the couture and accessory markets. The dream of large-scale adoption remains downstream, limited by the labour intensivity of production.

One challenge is that the field is not yet demand driven; it is technology innovation driven. User-centered design would be of value. Mass market opportunities lie in practical needs and at least a component of design research needs to address these with aesthetically powerful solutions that are sustainable.

A second challenge is the need to use simple technologies elegantly. The uptake of thermochromic inks indicates that commercial designers are interested in pushing the aesthetic applications more than gadgetry that may break down.

A third challenge is how to best aggregate research efforts to avoid duplication and enable interdisciplinary capacity between universities, art and design institutions, design companies and potential distributors. International research networks are a strong means for such collaboration and dissemination.

A fourth challenge is the need to provide a comprehensive visual data base that can act as a resource to emerging designers and artists in this field. This would be a worth industry-based investment.

Finally, a critical assessment of the ethical, social, economic and environmental issues in wearable technology and its applications needs to continue. Engaging those outside of the art and design world in these dialogues through presence at industry forums is critical.

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