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Interactive Garments: Flexible Technologies for Textile Integration

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***Abstract*—**Upon reviewing the literature and the pragmatic work done in the field of E- textiles, it is observed that the applications of wearable technologies have found a steady growth in the field of military, medical, industrial, sports; whereas fashion is at a loss to know how to treat this technology and bring it to market. The purpose of this paper is to understand the practical issues of integration of electronics in garments; cutting patterns for mass production, maintaining the basic properties of textiles and daily maintenance of garments that hinder the wide adoption of interactive fabric technology within Fashion and leisure wear. To understand the practical hindrances an experimental and laboratory approach is taken. "Techno Meets Fashion" has been an interactive fashion project where sensor technologies have been embedded with textiles that result in set of ensembles that are light emitting garments, sound sensing garments, proximity garments, shape memory garments etc. Smart textiles, especially in the form of textile interfaces, are drastically underused in fashion and other lifestyle product design. Clothing and some other textile products must be washable, which subjects to the interactive elements to water and chemical immersion, physical stress, and extreme temperature. The current state of the art tends to be too fragile for this treatment. The process for mass producing traditional textiles becomes difficult in interactive textiles. As cutting patterns from larger rolls of cloth and sewing them together to make garments breaks and reforms electronic connections in an uncontrolled manner. Because of this, interactive fabric elements are integrated by hand into textiles produced by standard methods. The Arduino has surely made embedding electronics into textiles much easier than before; even then electronics are not integral to the daily wear garments. Soft and flexible interfaces of MEMS (micro sensors and Micro actuators) can be an option to make this possible by blending electronics within E-textiles in a way that's seamless and still retains functions of the circuits as well as the garment. Smart clothes, which offer simultaneously a challenging design and utility value, can be only mass produced if the demands of the body are taken care of i.e. protection, anthropometry, ergonomics of human movement, thermo- physiological regulation.

***Keywords*—**Ambient Intelligence, Proximity Sensors, Shape Memory Materials, Sound sensing garments, Wearable Technology.

I. Introduction

SMART textiles can be broken into two different categories - aesthetic and performance enhancing. Aesthetic textiles include everything from fabrics that light up to fabrics that can change color. Designers, theorists as well as market forecasters, tend to split the world of wearable technologies into military, medical, industrial, sport and fashion applications. While the first four areas have exhibited steady growth, fashion is at a loss to know how to treat technology and bring it to market [1]. Fashion and leisure wear is another important consumer market, and here brands, engineers and fashion designers like- Schoeller textile AG, Esprit, Peratech, Phillips, Roet, Hussein Chalayan, Mark Eisen, Daniel Cooper, Marie Blaisse, Vibeke Risberg, Yin Gao etc. have demonstrated great ingenuity from haute-tech fashion to everyday wear. The quicker and easier development of electronics has made it accessible to designers and thus resulting in development of smart textile applications that are more interesting conceptually and aesthetically. E-textiles, also known as smart garments, smart clothing, electronic textiles, smart textiles, are fabrics that enable digital components and electronics to be embedded in them. An electronic textile refers to a textile substrate that incorporates capabilities for sensing, communicating, power transmission, and interconnection technology to allow sensors or things such as information processing devices to be networked together within a fabric. Most research and commercial e-textile projects are hybrids where electronic components such as conductors, integrated circuits, LED's etc. may or may not be constructed completely in textile forms by using conducting textile weaves [2]. To obtain information for wearable devices components such as sensors are often used, for instance, environmental sensors, global positioning system receivers, galvanic sensors, sound sensors and cameras. One of the most important issues of E-textiles is that the fabrics should be made so that it can be washable and the electrical components in it should be an insulator at the time of washing. Also while doing so; the textile should maintain its basic properties of suppleness, stretch, bending and flexibility in its use. Clothing will be part of the ambient intelligent environment in the future. Tomorrow's garments will do much more than just look good and feel great. They will have an intelligence of their own. According to Forbes, 71% of 16-to-24 year olds want wearable tech [3]. The next decades will see the gradual convergence of nanotechnology, biotechnology, information technology and cognitive technologies.

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A. Structure Features and Manufacturing Process

Normal textiles cannot be used for the transmission of power or signals, so other materials have to be integrated [4]. Most materials used as conductive fibres are already used in normal wires (carbon, polymers, polymers with nickel, copper and copper with silver coating). The use of correct material is according to the intended usage of the textile so that the fabric should be lightweight, durable, flexible and cost competitive. In the majority of cases copper is used for signal transmission and power. The copper wires are normally silver-plated for corrosion resistance. If these smart textiles are supposed to be exposed to humidity the wires are insulated by an additional polyester or polyamide coating. Electrical contacts to the conductive fibres woven or embroidered to the surface of the textiles can be made by crimping, soldering or using conductive adhesives.

"Techno Meets Fashion" (intersection of design, art and science) has been an interactive fashion project where sensor technology was embedded with garments that resulted in set of eight ensembles that were Light emitting garments (optical fabrics, Electro-luminous wires and LED's), sound sensing garments, proximity garments, shape memory garments etc. In these wearables, clothing is utilized as a communication device that reacts to the outside world. The project has a set of garment collection that had been successfully designed with the LilyPad Arduino; a microcontroller board designed for wearables and e-textiles. LilyPad Arduino– is stitched together with conductive thread to create interactive garments and accessories. LilyPad can sense information about the environment using inputs like light and temperature sensors and can act on the environment with outputs like LED lights, vibrator motors, and speakers.

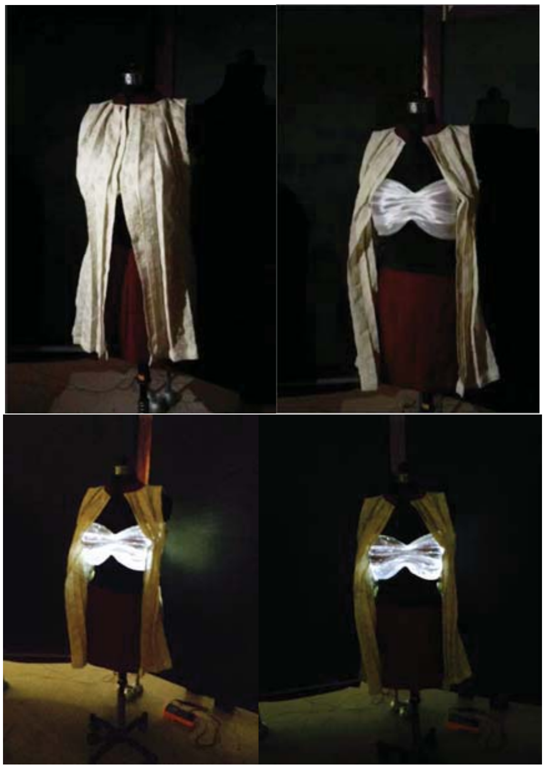

Fig. 1 Interactive garment made to react to music with integration of Shape memory wires and Polymeric optical fiber fabric

The project has set of garments that are equipped to function when exposed to music and the movement in the garment is made possible with the muscle wire (Fig. 1). The two-piece garment has the torso that is made of optical fiber fabric and the pleated linen jacket where the muscle wire has been integrated. This muscle wire is an extremely thin wire made from Nitinol (a nickel-titanium alloy) that is known for its ability to return to its original shape when deformed and heated. These are shape memory alloys and polymers (Fig. 2). A shape memory alloy is usually in the shape of a spring. The spring is flat below the activation temperature but becomes extended above the activation temperature. Apart from purely giving it a dramatic look in fashion; by incorporating these alloys between the layers of a garment, the gap between the layers can be substantially increased above the activation temperature, which considerably improves protection against external heat. Shape Memory Polymers have the same effect as the alloys but, being polymers, are potentially more compatible with textiles. The shape memory effect is observed when a plastic conforming to one shape returns, at a particular temperature, to a previously adopted shape. Nitinol can be self-heated, by applying current. Although thin and lightweight, yet the muscle wire can lift many times their weight and are able to do 100 times more work per cycle than the human muscle. The hardest part about using muscle wire is controlling the amount of current running through the wire. One can give it enough dramatic effect, but not so much current that the wire burns out and stops contracting. One simple technique is to look at the target current and then use Ohm's law (voltage = current x resistance) to calculate the voltage that is needed to maintain the amount of current based on the length of wire required. Fabric with integrated shape memory alloys could stretch, shrink, and bend on command; making it easier to even incorporate in garments to encourage correct posture.

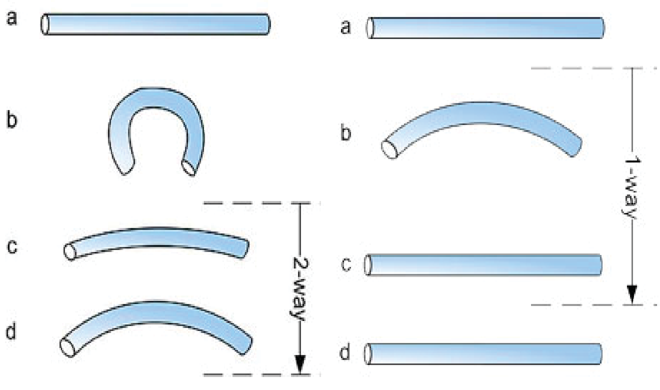

Fig. 2 Two common shape-memory effects are one-way and two-way shape memory

Intelligent systems integration with clothing, accessories, upholstery, or industrial technical textiles should enable higher user-comfort and performance. Flexible display units have provided new possibilities for creative design in architectural and industrial art applications for public premises, vehicles, and other related upholstery.

To complement the collection another garment has been designed around the optical fibre fabric; special fabric which incorporates hundreds of very fine optical fibres woven into it (Fig. 3). Polymeric Optical Fibre (POF) is used for simple light guide and illumination applications. The polymer optical fibre materials can be utilised in flexible lighting elements which can be combined with textile structures. The POF woven fabrics are introduced as a flexible alternative to lighting elements. The fibres can be illuminated by either LEDs or Lasers, depending on the specific circumstances of the installation and thus creates dramatic effects as per the music in the garment. Further, the set of two garments are worked with Proximity Sensors in which the sensors detect the presence of nearby objects without any physical contact in the range of 3m with the help of Sound, just like SONAR (Fig. 4). The output of the proximity sensor is observed through the speed of opening and closing of the fan head gear, which is connected with a thin conductive wire to the servo motor. The speed of the fan head gear is such that the closer one goes the faster the fan moves.

Fig. 3 Interactive garment with the torso made of Polymeric optical fiber fabric that gives a rhythmic display of lights reacting to music

Fig. 4 Black Ikat print Interactive garment integrated with proximity sensors, servo motor

To compliment the same another garment is created with the white pleated skirt where along with the movement in the fan neckline the LEDs fixed on the pleat of the skirt changes their brightness according to the distance of the object from the garment (Fig. 5). The closer the object comes to the garment, brighter it gets.

The garments have proximity sensor on its neckline which senses the distance of the object from the garment. The servo motor attached to the fan of the garment which works according to the distance between the sensor and the garment. The closer the object comes to the garment, the faster will be the speed of the opening and the closing of the fan which is attached to the motor (Fig. 6).

The luminous textiles have found a revolutionary new way to enhance interiors with light, texture and dynamic visual content. A totally unique ambient lighting system can be created where multi-coloured LEDs can be integrated seamlessly within beautiful white or coloured textile panels. And because of the range of fabrics and the sheer flexibility of the content, its creative potential is phenomenal.

Fig. 5 Pleated skirt Interactive garment intehgrated with proximity sensors, servomotor and LED's

Fig. 6 Movement of the fan with the help of servo motor attached to the neckline which reacts to the proximity sensor

The combination of soft, diffused light and the aesthetics of the material creates a very special effect. With total design freedom and completely customizable content, luminous textile makes the possibilities for mood creation endless. These soft textures of the panels have also seen its advent into architecture thus soothes the auditory senses. Unlike hard materials such as glass, concrete and steel that create acoustic problems of their own, luminous textile helps to dampen noise and soften echoes. Luminous textile panels can play a decorative, as well as practical role everywhere from spacious office reception areas and restaurants to hotels and airport lounges [5].

Contrast & Radiance has been the inspiration for the formal garment with the use of multicoloured LED's along with crystals (Fig. 7). The black velvet skirt radiates two contrasting colours (Fig. 8). The garment portrays contrast in more than a single metaphor. The concept is fun and melodious, though constructed for a formal garment. The LED's were stitched at an angle with the crystals so that the light reflection creates an Arora. The LEDs attached to the formal straight fit black skirt is made to react to the music because of its attachment with the amplifier module. And thus it shows in the rhythmic display of these lights.

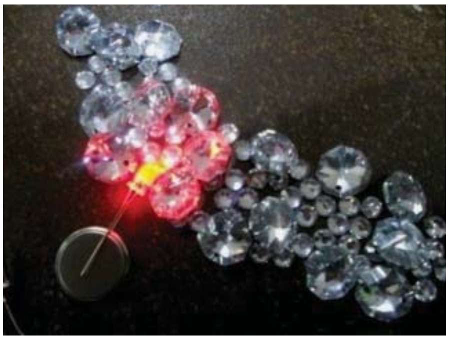

Fig. 7 Multicolored LED's along with crystals

Fig. 8 Contrast and Radiance – The black velvet skirt radiates two contrasting colours

The final look of interactive garments has been created with the denim sporty looking jacket by giving it a complete shift through to a retro look (Fig. 9). This has been made possible by adding the electroluminescent wires as an element of enhancement and make it react to sound giving a sequential pattern. There is coating of electroluminescent material over a copper wire, when we create an electric field across the chemical with the ac voltage passed by the battery then the light glows.

Electroluminescent wire (Fig. 10) is a thin copper wire coated in a phosphor which glows when an alternating current is applied to it. EL wire's construction consists of five major components. First is a solid-copper wire core, coated with phosphor. A very fine wire or pair of wires is spiral-wound around the phosphor-coated copper core and then the outer ITO conductive coating is evaporated on.

Fig. 9 Denim jacket embedded with EL wire in synchronization to music, thus allowing multiple lengths of EL wire to be flashed in a desired sequence

Fig. 10 Electroluminescent wire

This fine wire is electrically isolated from the copper core. Surrounding this "sandwich" of copper core, phosphor, and fine copper wire is a clear PVC sleeve. Finally, surrounding this thin, clear PVC sleeve is another clear, colored translucent, or fluorescent PVC sleeve. EL wire sequencers are used in the jacket to flash electroluminescent wire, in sequential patterns. This requires a low-power, high-frequency driver to cause the wire to illuminate. Most EL wire drivers simply light up one strand of EL wire in a constant-on mode, and some drivers may additionally have a blink or strobe mode. A sound-activated driver in the garment functioned in a way to light EL wire in synchronization to music, thus allowing multiple lengths of EL wire to be flashed in a desired sequence.

Today's ordinary clothing has the untapped power to become tomorrow's wearable electronics. Yet, there is some disagreement over the scope of Smart Fabrics. Broad definition states that Smart Fabric is traditional fabric with integrated active functionality. Smart Fabrics differ from Wearable Electronics in that wearable devices are merely contained and carried by clothing, where Smart Fabrics have the functionality of wearable devices actually integrated into the fabric. This is an important distinction to make, because several commercial products marketed as "Smart Fabric" are actually "regular" fabric that envelopes traditional electric, electronic, and/or electromechanical (EEE) devices [6]. All electronic devices require power, and this is a significant design challenge for Smart Fabrics. Human interfaces to active systems can be roughly grouped into two categories: input devices and display devices. Input devices can include capacitive patches that function as pushbuttons, or shape-sensitive fabrics that can record motion or flexing, pressure, and stretching or compression. Capacitive patches can also be used to sense physioelectric signals, which allow for user input via electromyogram (EMG) or electroencephalogram (EEG). The display devices may include fabric speakers, electroluminescent yarns, or yarns that are processed to contain arrays of organic light emitting diodes (OLEDs) [6]. Fabrics can also include elements that provide electrotactile feedback or simply vibrate.

Turning rigid electronic parts into stretchy, smart clothing material has been tough for researchers and manufacturers. It is a challenge to seamlessly blend “hard” gadget functions with “soft” objects without making the human’s aware of what they are wearing. It has to be self-contained piece that can charge itself, store energy and perform useful functions. Otherwise, it's an extra burden that nobody needs in our lives. The problem with most of the soft electronics; the few examples that exist nowadays; is that people mostly just put chips or widgets onto textiles and try to enable interesting textile functions. Most of the electronics are not designed for soft interfaces. Some labs have tried embedding tiny nanoparticles inside ordinary cotton thread so that they can conduct electricity [7]. But the problem here is to address in making the material last a long time, as well as needing to use chemicals to bind the nanoparticles to the cotton. The technology of smart clothing may seem imminent, but psychological barriers remain because textile manufacturers are hesitant to work with completely new fibers.

Practical issues have hindered the wide adoption of interactive Fabric technology in mass production of casual wear. The process for mass producing traditional textiles cannot be followed with these interactive textiles. As cutting patterns from larger rolls of cloth and sewing them together to make garments breaks and reforms electronic connections in an uncontrolled manner. Because of this, interactive fabric elements are generally integrated by hand into textiles produced by standard methods [8]. Casual wear products need maintenance of daily washing, ironing etc., which subjects the interactive elements to water and chemical immersion, physical stress, and extreme temperatures; for which the current state of the art tends to be too fragile for this treatment. The state of the art in flexible electronics and nanotechnology, required to integrate power and computer processing elements into fabric, has not advanced to the point that analog processing or digital logic can be integrated into fabrics [8]. The result of this is that many products marketed as Smart Fabrics are really just traditional electrical and electronic components glued or sewn in to traditional fabrics, or inserted into pockets and channels in the fabrics. Even though some smart fabric elements are readily available (such as buttons, conductive swatches, and conductive wires for interconnects), they are not in widespread usage because of the manual effort involved to integrate them. Despite these challenges, many companies are exploring potential commercial applications for interactive fabric technologies. As the enabling technologies mature and more companies develop the necessary expertise, interactive fabrics will move from novelty and niche commercial markets to more mainstream applications.

II. Conclusion

Smart textiles/ interactive textiles, especially in the form of textile interfaces, are drastically underused in fashion and other product design. Surely, the market for consumer goods particularly in the luxury market for textile interfaces in yet to be tapped. The few garment-integrated technology products that have overcome significant obstacles and reached the commercial market have often avoided the issues of high-level integration of electronics and apparel production processes by using electronics designed as stand-alone units, which are then integrated into garments by way of special pockets, embedded conductors, or other minimal means of attachment [9]. This solution has reduced problems with the actual manufacture of products, but success has been less evident in consumer acceptance of such devices. Interactive garments represent the next generation of textiles affiliated in both research and commercial activities. Working on this project has given an overview of different research and commercial activities for further discussions on how interactive garments could be introduced in fashion. As per the literature review and the market study, there has already been an introduction of interactive textiles in fashion; however, the efforts of introducing interactive textiles in other clothing areas like sportswear, medical, military etc. are still dominating the research activities. In fashion the applications are more focused on visual or tactile feedback from the wearer.

While there are many commercial items that suggest the future use of interactive fabric technology, yet currently available consumer interactive fabric products are not highly integrated; most can be better described as Wearable Electronics; rigid electronics and standard wiring mounted on fabric [6]. They generally gather user actions or sensor data and in some cases are marketed on the novelty of the technology rather than the functionality of the product. Power from an external source is usually required or standard consumer batteries are used. Very few commercially available products integrate flexible displays, though some incorporate lighting and indicator LEDs [6].

In order to meet these challenges, firstly there needs to be more demand in order for development to really take off. There has to be a need of some sort of market pull that gives interactive garments a reason to be there. We are increasingly a mobile society, accustomed to having access to information and entertainment anywhere at any time, Smart textiles enable the development of devices and systems that further enhance our mobility and our ability to do more while on the go [10]. The market for smart textiles and wearable technology has the potential to change the way people dress, communicate, respond to emergencies, manage their health and even entertain themselves. There is a scope that the interactive textiles and their additional functions are well-received and bought; provided that they do not disturb the user, are easy to handle and offer an extra benefit. Interactive textiles are products which can make people's lives better and more worth living.

Textile sensors can be stretchable, washable, unobtrusive and more comfortable. On top of these, the products can be designed by using natural textile properties like patterns, structures, and hundreds of textile materials. The focus on building an intelligent environment into everyday items is leading to the rapid evolution of wearable computers and electronics, benefiting the market for smart fabrics and interactive textiles. The market also reportedly stands to benefit from technology developments and innovations in the field of integration of electronic devices into textiles at the yarn level, as well as performance and functionality improvements in integrated textile sensors, switches, interconnects etc. The global market for smart fabrics and interactive textiles is projected to reach $2.6 billion by the year 2017, according to a new report from Global Industry Analysts Inc. [11]. Growth will be primarily driven by developments in material science and fiber technologies (i.e., nanofibers, conductive pressure-sensing fabrics and other hybrid fabrics), as well as the growing miniaturization of electronics.

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Recent Papers presented in various National and International Conferences and Exhibitions:

1. Speaker for "Futuristic Fabrics- Smart Textiles" in the "International Conference on Technical Textiles in Apparel sector"- NIFT Bangalore on 21-22 November 08.
2. Speaker for "Futuristic Fabrics- Smart Textiles" in the National Seminar on "Converging Science and technology for better lifestyle by Mount Carmel College- Bangalore- India- 24th -25th February 2009.
3. Paper Selected for Poster presentation on "Futuristic fabrics- Smart textiles" in the 2nd world conference on 3D fabrics- South California-USA on 6th- 7th April 2009.
4. Speaker for "Value added finishes" in the international conference by Team Tech- Bangalore- India- on 16th-18th April 2009.
5. Speaker for "Sustainable Fashion- Intellectual Property rights in fashion Design" in the international conference by Society of Dyers and colorists (SDC)- Chandigarh- India- on 1st June 2012.
6. Speaker for "Technology intervention in surface modification through mix media techniques within fashion and Lifestyle Industry". Sixth World Conference on 3D Fabrics and their Applications by TexEng Software Ltd, Manchester, UK and NC State University College of Textiles held on May 26-28, 2015 in the College of Textiles, NC State University, Raleigh, NC, USA.

Reviewer (2008) for the course "Introduction to textile Material" for the Distance Learning Programme in Fashion Design set by Pearl Academy of Fashion with Indira Gandhi National Open University.

Working Projects- Developing garments with Fashion design students to enhance the ramp appeal- (Sensor technology embedded with textiles/ garments) - Light emitting garments, sound emitting garments, proximity garments.