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Evolution of Fashion Design in the Era of High-Tech Culture

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***Abstract*—**Fashion, like many other design fields, undergoes numerous evolutions throughout the ages. This paper aims to recognize and evaluate the significance of advance technology in fashion design and examine how it changes the role of modern fashion designers by modifying the creation process. It also touches on how modern culture is involved in such developments and how it affects fashion design in terms of conceptualizing and fabrication. The methodology used is through surveying the various examples of technological applications to fashion design and drawing parallels between what was achievable then and what is achievable now. By comparing case studies, existing fashion design examples and crafting method experimentations; we then spot patterns in which to predict the direction of future developments in the field. A breakdown on the elements of technology in fashion design helps us understand the driving force behind such a trend. The results from explorations in the paper have shown that there is an observed pattern of a distinct increase in interest and progress in the field of fashion technology, which leads to the birth of hybrid crafting methods. In conclusion, it is shown that as fashion technology continues to evolve, their role in clothing crafting becomes more prominent and grows far beyond the humble sewing machine.

***Keywords*—**Fashion design, functional aesthetics, smart textiles, 3D printing.

I. Introduction

IT is common knowledge that the environment we live in greatly influences the style of clothing that people wear. And, it is not just referring to the physical-geographical or climatic environment but rather the less tangible aspects of the socio-cultural environment which is related to the time period we live in as well as the prevalent culture at the time. As much as clothing is a practical necessity, it is also an expression of identity and a reflection of culture.

In the current high-tech culture we live in, there is a trend of using computers, automation, and other technology driven methods to compliment many fields, fashion design is no exception. Designers now immerse themselves in the age of smart textiles and incorporate modern technology with fashion design and production. The used of sensors, conductive fibers and other smart fabric technologies like 3d printing, brings a whole new dimension to fashion design in terms of functionality, expression and interaction. The design focus is also shifted to more active issues of personal identity, social behavior, and intuitive interactions.

Fueled by society's eagerness for efficiency, the fashion industry is on the verge of a revolution. The boom of technological advancements prominently redefines the role of fashion designers, their approaches to design and functionality of fashion. This ultimately transforms the conventional design process.

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II. Trends and Methodologies

Traditionally, clothing is a means of fulfilling basic needs such as protection from the elements, comfort, camouflage, and even socially accepted modesty as well as a medium for symbolic, artistic or religious expression.

Early concepts and constructs of "smart clothing" was very far from the current ideals of "smart clothing", attempts to make wearable technology in the 1970s were more inclined towards simply using clothing as a support for electronic attachments and had very little to do with fashion [1]. However, this changed when a different approach was used; resulting in the smart fashion we have now. Aesthetics and function are sometimes thought as independent of each other or even antagonistic, there may be misconception that aesthetics is less important than practicality. What is often neglected is that these two concepts are interrelated and have a symbiotic relationship. Fashion is linked with design, and design aims to fulfil needs of the consumer whether it is aesthetic or functional. Thus when a designer engages in effective fashion design and undergoes the process of satisfying certain variables, it is fundamentally the same process that sates functionality. Consequently, by working with fashion as the starting point and integrating technology simultaneously while pursuing it as a distinct hybrid topic of wearable technology; it helps in creating a more effective outcome. Thus, with the advent of smart garments and wearable technology, clothing is rapidly transformed into an interactive interface between wearer, garment, and environment. The development of clothing as technological interface is highly influenced by the development of technology as fashion designers are drawn by the expanded possibilities of high-tech wearables.

The human body is itself a biological receptor interface, it has been mentioned that clothing and fashion has an intimate relationship with the human body in both physical and social aspects. With smart garments, fashion becomes an additional interface and results in a cyclic interaction between body, clothing and environment. Take for instance the research project *SmartSecondSkin* (2004) by Jenny Tillotson and Adeline Andre which comprises of a scent delivery system that is programmed to respond to the wearer's emotions and dispenses olfactory stimulus for aromatherapy to alter the wearer's mood [2, p.94-96]. This is an example of a complex feedback design. Firstly, the wearer's mood changes, possibly

reacting to a conscious or subconscious stimuli in the environment, this emotional response becomes an input that triggers the sensors and produces an output, in this case, it is the dispensed aromatherapy which in turn brings the wearer's emotions back to a desired state as a feedback. The body, environment and clothing interacts accordingly, this interaction is modulated by what is being programmed into the technology involved.

Technology goes a long way in making certain design concepts viable. "*Palpitations*" [3] is a dress designed with the purpose of projecting internal reactions externally onto the dress. The proposed concept was that the butterfly headdress, symbolic of dreams and thoughts, is programmed to flutter in response to brainwaves detected from a sensor, in conjunction with the pulsation of rippling light down the front of the dress that reacts to the pulse sensor. The two sensors express the idea of rationality versus emotional response, and plays with the supposed notion that females are more emotionally inclined. Here, it is demonstrated how Nth-Light® [4], a revolutionary flexible LED is used with sensors to create a dress that questions the socially perceived idea of female temperament, and it shows how technology is used to provide an insight to the body's internal workings. This design would not have been possible if companies did not develop flexible LED compared to what were once rigid bulbs of lights. This gradual development of technology can be easily observed through the works of various fashion designers throughout our time. When comparing "*Palpitations*" that uses flexible LED to Atsuko Tanaka 1956 *Electric dress* [1, p.105], the evolution is startlingly discernible. Both dresses are a reflection of how technology becomes part of our culture and permeates into fashion and also shows the prevalent need of artists to include current cultures in fashion. Tanaka's Electric dress is inspired by modern industrial technology and is a step towards the idea of avant garde fashion in which Tanaka was thought to be one of the pioneers in. As technology improves, works like "*Palpitations*" takes the combination of fashion and technology one step further into the realms of concept and interactions, the idea of a more active participation between wearer and garment. Furthermore, aside from the noticeable direct influence of a high tech culture in the above examples, comparing Tanaka's *Electric dress* and "*Palpitations*" is not only a good gauge on the development of technology in the fashion field, it also shows the co-influences of Design needs vs Technological improvements whereby on one hand, the technology is a sources of inspiration, on the other, design inspires the need for better improved technology in order to realize certain design aspirations

"*Transcendent*" is an interactive dress by Mihaleva that communicates with its wearer by translating the body's movement into a corresponding light pattern. The seamless top made from melded Sahara white leather and a 100% silk organza skirt are aesthetically embedded with functional technology, becoming a dress with its own way of expression. A collar extension on one side of the dress has embedded within it a flex sensor that responds to the body's movement, this is processed by a microcontroller which controls the illumination pattern of the LED array; it is powered by a lithium-polymer battery. The tiny LED lights embedded into the "skin'' of the dress fade in and out according to the intensity of movement and have become a decorative language. Light (as in opposition to heavy), works as something that floats in an ethereal manner on the textured, leather surface. The light is a metaphor for enlightenment and striving for passion. The dress is the ultimate wedding dress that expresses emotions and communicates on another level where body and mind or body and desire can be in two places at once. In essence, a saintly aura appears around the wearer as well as that of "new celebrity." It is an example of the application of technology to express concepts as well as to fulfil certain contextual need of a given situation (e.g. that of a wedding), or fulfil the aforementioned idea of "function of aesthetics".

Another dress following the series is "*Allure*" which aims to explore concepts of our bodily engagement with posture. The incorporated conductive stretch sensor is to realize wearable kinesthetic garments able to detect posture and movement of the user. The unique knitted stretch sensor is an aesthetic exploration of textile technique mapped to the body. The stretch sensor, based on the changing length will send signals to the lily pad Arduino and the vibrating motor, to bring awareness to the wearer about their posture. This project once again demonstrates the cyclic matrix of interaction between garment, wearer and environment. In this example, when the person slouches or bends in a certain way, it is mirrored in the light that is produced. This is then made obvious to the audience, whereby the audience might respond or at the very least be given a piece of information about the wearer that they are free to interpret in any way. And because the circuit is programmed or made to react in a particular way to the changes in the posture, there is fundamentally a pattern to it, thus the wearer becomes integrated into a minimally predictable pattern. On the other hand, it could be a point of interest to look at the potential "practical" or scientific aspects of how this dress could help improves posture, or used to study the effect of body movements on clothing. Future developments on more in depth studies could possibly lead to new ways of making longer lasting, more comfortable or more material efficient clothing. In short, technology could give us a clearer picture of how a person wears clothing, which might in turn provide a means of creating "better" clothing.

The availability of customizable circuit kits specialized for interactive wearables play a great part in propagating wearable technology. One of the main issues with fashion technology is maintaining the integrity of electronics in clothing, ensuring that with the constant wear and tear that clothing undergoes, the embedded electronics are still able to function. This is why specialized clothing-adapted electronics like conductive threads are important for this field. For example, the LilyPad Arduino [2, p.119] developed with SparkFun Electronics consist of electronic components that can be easily sewn into fabric and programmed to react to certain variables. Suitable tools and starting components like these are important for wearable technology to flourish.

"*Text-ile Landscape memories*" by Galina Mihaleva is a collection of interactive haute couture dresses inspired by the beauty of culture and tradition of the Southwest and South East Asia. In this collection, the dresses are based on a multisensory design. They employ the property of conductive threads to act as contact points that remotely connects to the audio and visual displays. Sensors in Lilypad kits supports tactile based multisensory systems that are useful in interactive artworks as well as a multisensory teaching aid. And it is not just SparkFun, several other new companies took the opportunity to jump onto the DIY electronics bandwagon. Adafruit founded in 2005 by Limor Fried is one such company [5], followed by hardware company TinyCircuits which started in 2011. One of the products advertised by TinyCircuits is an even smaller processor board 1/12th the size of a Lilypad Arduino targeted for use in E-textile projects [6]. The fact that there are still companies eager to break into the E-textile market is a good indicator of its growing popularity; what's more, companies are improving on the electronics for e-textiles. It is likely that this momentum will continue if fashion designers keep up their foray in wearable technology.

"*Reflux*" by Mihaleva, is a dress made from 3D tactile fabric, using fabric as an interface and consists of XB anathemas, Lilypad Arduino, accelerometers, and conductive thread that controls the audio as well as the visualizations projected onto three screens [7]. The sound and projections are "played" and manipulated by the fluidity, flexibility and mobility of the skirt. Technology reinterprets movements into visual audio outputs. It aims to highlight the unique relationship between the three domains of Sound, Visual and Movement. It is another example where technology acts as a translator between different domains.

While textile can turn into a technological interface, some designers are soon inspired to look at material fabrication technology itself. The exploration of such possibilities spurred the need for interdisciplinary approaches. Designers become more than artists, they turn into engineers, programmers, chemists, and even biologists. *Micro'be' Fermented Fashion* is a project where organic fabric is "grown" with the bacteria through the process of bacterial wine fermentation. The cultivated fabric formed from cellulose micro fibrils is biodegradable and can be used to make seamless garments [2, p.83]. Its advantages of being environmentally friendly and a lower cost fabric production in the wake of rising petroleum costs for synthetic fabrics only came to be when the artist vision extended across into the biological fields. This can only serve to prove the benefits of hybridizing interdisciplinary methodologies. In addition, there is another implication of cultural influence, high-tech culture is characterized by the drive for efficiency, the need to improve current conditions, and the use of highly scientifically advanced methods (e.g automations, Bio-culture etc.) to achieve these improvements. In recent years, society starts to realize the impact of finite resources, thus leading to a trend of conservation awareness that inspires projects like *Micro'be' Fermented Fashion.* The attention to environmental concerns lets life sciences become a popular theme in technology related fashion, where ideas for cultivating textile in labs came up.

In an upcoming series of dresses entitled "*Living Interactions*", the idea of interacting with plants is explored by forging symbiotic relations between the human and the plants. A fabric base is constructed by crisscrossing stiches and incorporating various threads, wool and even palms tree husks. These are sewed onto a water-soluble interfacing (sometimes referred to as a water soluble stabilizer), this stabilizer is then dissolved in water to produce a "cloth" collage of threads and fabric pieces. This mesh-like "fabric" acts as an anchor to a collection of Air plants of the tillandsia genus where the roots are meticulously woven into the thread-fabric mesh. Plants have been known to interact to external stimuli, the most prominent being sunlight. Green plants are also known to perform photosynthesis and produce the ever-essential oxygen. The human wearing the garment becomes a mode of transport for the Air plants while the Air plants become a collar of natural air purifiers. Life science and biological conventions, being technology related as they are, are drawn into the fashion world. Our technologically focused culture allows for a more liberal definition of what constitutes as textile and fashion.

The definition of textiles is constantly being challenged; designers now not only look at textile with technology but also the technology of textile production. This leads to the development of innovative and unconventional "textiles" like Fabrican, a spray-on fabric that has the potential to become a useful advertising and marketing tool [1, p.31].

A notable fabrication tool is 3d printing, which has made a significant impact on the fashion industry. It is garnering a lot of interest, or at the very least, the prospects of it is favorable, evident by the fairly well received 3d printing competition held at the Singapore Nanyang Technological University. 3d printing was initially seen as a very useful tool for product design and medical support purposes until fashion designers like Iris Van Herpen discovered its potential in architectural fashion. Van Herpen won critical acclaim for her intricate 3d printed dresses [8, p.50], her success sparked the growing trend of 3d printed fashion, and be it dresses, jewelry, or shoes, 3d printing is becoming a popular tool for fashion designers, and it is now easily accessible with the availability of affordable desktop 3d printers. Even within the fields of 3d fashion, there are a variety of crafting methodologies; form, material, texture and colour can all be conveniently manipulated.

Collaboration between scientists from Disney research, Cornell University and Carnegie Mellon University has given rise to the 3d printing of soft interactive objects made from layers of conductive fabric [9]. Design studio Nervous System has come up with a process to 3d print a dress out of plastic but still behaves and flows like fabric [10]. As 3d printing gets a foothold in fashion, a team of engineers in San Francisco have built an Electroloom that acts like a 3d printer for fabrics by using a solution blend of polyester and cotton sprayed onto a template to create a seamless garment [11].

3D systems corporation, specializing in 3D technology, introduces to the market an app known as Fabricate™ that is

used with their Cube 3D printer [12]. It combines the aspects of 3D printing and fashion in a very literal manner whereby fabric is sandwiched between the layers in the 3d printed constructs. The modular units are hence attached to a nylon mesh textile which can be made into embellishments for garments. This Fabricate™ technology is utilized for an upcoming "Modular Geography" dress collection, the modular units' height and form are manipulated such that when drapes over the body, they create an appearance of a "landscape" over the body. Depending on the design of the dress, the modular units being attached to cloth will move and flow with the cloth as the person wearing the garment moves. These various new high-tech methods of crafting provide more tools and techniques for fashion designers to explore and express.

While designers embraced the technology of material fabrication, traditional fashion design processes and sensibilities are gradually being amalgamated with high-tech methods to produce brand new crafting methodology, hence the design process is inevitably altered to accommodate for it. This brings one to the topic of Computer Aided Design (CAD). For 3d printing, CAD is needed to create a 3d model for printing. Patterns were used to produce clothes industrially since the invention of the sewing machine in 1830 [13], with the use of CAD, designers create their designs on the computer instead of drawing it on paper. CAD and 3d printing either bypasses or changes many of the conventional process of tailoring. Furthermore, computers can be utilized in many ways to create textile designs, for instance, coding can produce interesting computer generated patterns. Certain innovative techniques involve taking advantage of transitional design effects arising from translation of the physical to digital with technology such as scanning. Japanese textile company Nuno is renowned for combining tradition and technology to produce beautiful woven fabrics. *Woven structure pattern 1984* is a fabric designed by Nuno founder Jun'ichi Arai by repeatedly photocopying an African kente cloth until it becomes pixelated; it is then scanned and woven on a computer driven Jacquard loom [14].

A more straightforward use of computers is to produce the design directly with illustration software or drawn by hand and scanned in before printing digitally on cloth. Alternatively, vector designs can be sent to laser cutters to cut out shapes in various materials. This method was used to create the cut felt in the "*Text-ile Landscape memories*" dresses. Laser cutting is a fast and convenient method to produce planar designs. It is able to perform sophisticated cuts on several types of materials whether it's metal, plastic, wood, felt or paper. The setting just needs to be adjusted according to suit the material. Such automations save time for designers so that more time could be allocated to the creative aspects of the designing. These are all instances of how the technology alters the crafting methods in fashion, as previously mentioned, the type of technology influences the type of fashion. In "*Text-ile Landscape"* the planar felt material is laser cut and then manipulated to adapt a three-dimensional form. The precise nature of laser cutters and 3d printers inspire a more architectural take on fashion. It can be said that technology inspires a more geometric, clean-cut, "futuristic" style.

The accessibility and advancement of technology changes the playing field of the fashion industry. Traditional tailoring requires a significant amount of time when measuring clients for a perfect custom fit, but a 3d scanner is able to quickly obtain accurate three dimension measurements within seconds [8, p.24]. A recent service known as bodi.me utilizes body scanners to allow customers to match their sizes to outfits purchased online based on sizing information from registered fashion companies [15]. Imagine if the 3d scanners are combined with 3d printing of garment, perfectly fitting customized clothing could be efficiently and rapidly produced; this would drastically reshape the manufacturing process in fashion design.

III. The Observed Pattern

Throughout all the examples, it should be noted that there is a pattern. Firstly, there are constant improvements in technology and designers tend to make full use of these tools for their designs, subsequently affecting their design concepts.

Secondly, hybridization is rampant in wearable technology. Fashion is a complex and established long standing industry, hybridization is almost unavoidable in order to integrate advanced technology into a field with such a long history. This gives rise to new or combinational crafting or design techniques.

There is a correlation between wearable technology designs and the concepts they tend to express. The input and output principles is by virtue of the systemic nature of technology. It is therefore naturally geared toward issues pertaining to interactions, social or otherwise. And since fashion is basically an adornment of the human body, expression of identity and perceived culture becomes a common and favored theme.

The rise in wearable technology can be said to be a reflection of our current culture. Availability of specialized kits like Lilypad kits is indicative of the market for wearable technology. It is likewise proof of the codependence and co-influencing between technological advancement and design aspirations of fashion designers. Technology fuels inspiration, and aspirations spurs development.

IV. Conclusion

Conclusively, the various examples of projects examined in the paper show that as technologies continue to evolve, their potential uses in smart clothing grows exponentially, and it simultaneously affects and is affected by the fashion culture. Furthermore, it demonstrates the role and importance of wearable technology in our current high-tech environment and expands functional and expressive possibilities for the modern fashion designer.

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