한국의류산업학회지
제21권 제4호, 2019
<연구논문>

pISSN 1229-2060
eISSN 2287-5743
Fashion & Text. Res. J.
Vol. 21, No. 4, pp.420-431(2019)
https://doi.org/10.5805/SFTI.2019.21.4.420

Digitalized Dynamic Fashion Design: Graphical Patterns in Motion

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Abstract: This paper evaluates the potential of dynamic graphical patterns in future-driven fashion design using computer graphics that enables changes to the visual appearance of a textile for aesthetic, expressive or communicative purposes. In particular, it focuses on experimenting with the possibility of creating digitalized dynamic fashion garments that are illustrated digitally using motion graphics developed collaboratively in a virtual space. Three objectives were formed and addressed. First, a dynamic graphical pattern was defined that also investigated the cases of tangible and virtual dynamic patterns in textiles and garments to identify current situations and future prospects in terms of functional techniques and expressive effects. Ten digital fashion illustrations were then created in collaboration with a group of graphic designers and motion artists to visualize dynamic graphical patterns changing over time. Four types of dynamic fashion illustrations were also introduced in their methodological and expressive aspects. Last, some findings resulted from digital works that led to implications for future studies on tangible dynamic fashion designs. This study proposed that computer graphics and digital imaging technologies integrated into a virtual fashion that creates eye-catching and futuristic dynamic fashion designs that can customize colors and patterns according to the desires of wearers or users.

Key words: digital, dynamic, fashion design, fashion illustration, graphical pattern

1. Introduction

With the radical development of textiles made from smart materials and computational technology, the area of fashion design has also tried to combine aesthetics and style with functional technology, intersecting different areas such as design, science, and technology. As new technologies heighten the potential of fashion garments as devices for experimental observations and practical advances both in conceptual and commercial designs, they also transform clothing surfaces into an interface for 'fashionable wearables'(Seymour, 2008), becoming a great vehicle for self-expression that is mediated and amplified through digital technology. Fashion image-makers have developed digital special effects, using two-dimensional(2D), three-dimensional(3D) and moving-image tools to present future visions, and fashion and textile designers have combined digitized techniques with traditional analogue versions of their work methods(Clarke & Harris, 2012). In addition, the Internet and social networks can also provide a creative platform to communicate and interact with personal expression and playful display between users, as well as designers.

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When we consider the nature of change that is inevitable for the fashion industry, the limitless and dynamic possibilities of clothing interwoven with technology look fascinating and show great promise for fashion design. In this paper, the author examines the concept of dynamic fashion design of textile patterns using computer graphics, which enables changes to their visual appearance for aesthetic, expressive or communicative purposes. Dynamic fashion is defined in this paper as textiles and fashion garments with varying, animated colors or patterns that visibly change from the fabric's underlying colors or patterns to others and then return to the initial color or pattern after a period of time. This demonstrates the potential of different digital expressions than can be programmed to this effect.

Since the early 2000s, there have been significant aesthetic and technological explorations of dynamic textiles and garments. Studies have been conducted on high-performance conductive materials and thermochromic inks that change colors, textures and forms within textiles(Berzowska, 2005; Orth, 2004; Post et al., 2000; Robertson et al., 2008). Berzowska(2005) presented an electronic textile(E-textile), Orth(2004) used a heated yarn, and Robertson et al.(2008) introduced a thermochromic, liquid crystal to create textiles that change color. Following this initial research, custom-made personal objects including dynamic textile patterns have communicated and interacted wirelessly with other systems integrated with the necessary technology(Worbin, 2010). Optical fibres and light-emitting diodes(LEDs) have created illuminating colors and sur-

face patterns, blurring the line between graphic art and digital information, as seen in Philips' emotional dress(2006), Hussein Chalayan's LED dress(2008), CuteCircuit's galaxy dress(2008), and so on. The common link connecting these examples is a valuable contribution to developing dynamic textiles or fabric-like surfaces that can be visually transformed through digital technology, which is an emerging field that is still limited in its application.

In previous studies, tangible dynamic textiles and garments have usually achieved a relatively limited range of pattern variability by changing color combinations. However, digitalized dynamic fashion garments that combine images from computer graphic software with portable hardware such as a mobile phone open up the possibility of creating revolutionary displays of patterns that include both still and moving images and that are more personalized and varied than tangible patterns. If fashion garments could have a computer screen's capacity for dynamically displaying colors, patterns, and still and moving imagery, how would innovative changes in the fashion industry be expressed in everyday life? Starting with this question, the author intends to unlock the potential of digitalized dynamic fashion garments represented in digital fashion illustrations using computer graphics in a virtual space.

As Quinn(2012) mentioned, garments are themselves emerging as complex, multi-faceted hybrid forms, and many digital applications have provided an array of multidisciplinary crossovers among digital media, textiles, fashion, electronic engineering and computer sciences. Digital fashion illustrations, the focus of this paper, also demonstrate results from collaborations via a social media platform between the author as a fashion illustrator and a group of motion graphic artists. The resulting virtual dynamic patterns have a more artistic and conceptual nature, rather than commercial or functional ones.

This paper addresses the following objectives:

First, it defines a dynamic graphical pattern and investigates cases of both tangible and virtual dynamic patterns in textiles and fashion garments. Then, it explores the current status of dynamic textile and garment patterns and the possibility of applying functional techniques and expressive effects to fashion design.

Second, it presents four cases of digitalized dynamic fashion illustrations developed using the methodology, which exemplify dynamic graphical patterns for future-driven fashion design. Collaborating with a group of graphic designers and motion artists, the author created ten samples of digital fashion illustrations with the theme of 'Psychedelia' to visualize experimental explorations of dynamic graphical patterns that change visually over time.

Third, it presents some findings and discussion points resulting from the experimental, digital work, which also revealed some implications for follow-up studies on tangible dynamic fashion design in the future. The virtual digital fashion illustrations serve as a starting point for developing tangible dynamic garment patterns and demonstrate the potential of fashion garments that integrate intimate, dynamic fabrics in the real world.

2. Theoretical background

2.1. Tangible dynamic textiles and garments: The typology and cases

Seymour(2008) coined the term 'fashionable technology' as being the intersection of design, fashion, science, and technology, and the term 'fashionable wearables' as being designed garments, accessories, or jewellery that combine aesthetics and style with functional technology. Current research on textiles and garments integrated with technology tend to involve not just technical dimensions but also emphasize their potential for personal expression and playful experimentation.

Digital technology today makes movement and change in fashion materials possible. Reacting to various dynamic variables, such as environmental conditions, specific materials, or computational technology, the colors and patterns of dynamic textiles and garments can change their aesthetic and functional expression during use, in contrast with traditional ones with fixed and static expressions. Worbin(2010) stated that a dynamic color is a color that temporarily disappears to reveal a fabric's underlying color or display another printed color. Mackey et al.(2017) considered dynamic fabric to be a textile with computational input that enables changes to its visual appearance for aesthetic, communicative and expressive purposes. Similarly, the author of this paper defines dynamic textiles and garments as those with a color or pattern that changes from the fabric's underlying color or pattern to another one or more different colors or patterns and then returns to the initial display after a period of time.

Since it is still an open issue on how to systematically identify the correlation between textiles and garments and changing colors or patterns, we can examine different technological principles and expressions of the changeable fashion materials, with or without computational technology(Worbin, 2010). Thermochromism(TC) provides a color change by heat; photochromism(PC) by exposure to ultraviolet(UV) light; and electroluminescence(EL) by light manipulation(i.e., holography) or by light transfer via optical fibres or luminescent materials. Some collaborative projects by textile and fashion designers within multi-disciplinary teams have presented examples of the three types of dynamic expressions and, sometimes, the interactive effects of garments or textiles combined with smart textiles or computational technology.

Some of the first textiles that featured TC usually had a con-

ductive section to provide dynamic colors and patterns by heat with electronic or computational approaches. Maggie Orth and her company, International Fashion Machines(IFM), created programmable, color-changing textiles that combine woven electronic circuits, printed TC inks, and drove electronics, bringing about interactive effects. 'Dynamic double weave'(2004) printed with a TC-ink formula explored how textile patterns with repeatedly changing colors can interact with a repeating software program. 'Running plaid' (2007) used a similar principle to add time and motion to woven textile patterns(Pailes-Friedman, 2016; Seymour, 2008; Worbin, 2010). Sara Robertson introduced TC liquid crystals to create color-changing textile patterns with organic and rounded shapes by laminating a conductive yarn with a TC-printed pattern(Robertson et al., 2008; Worbin, 2010). Linda Worbin created 'Fabrication bag' (2005), which exemplified a digital personal object that can be carried around, going beyond a simple example of TC. The pattern on the bag changed according to mobile phone activity, going from dull to colorful displays from heat elements mounted inside the bag, and then changing back to its first expression when the electrical power was switched off(Worbin, 2010).

Second, PC can change colors by exposure to UV light. In the 'Costume'(2006) experiment, Linda Worbin examined dynamic textile materials and patterns reacting to UV light, temperature or voltage. Heat elements were woven into the wall-hanging and were controlled by three circuit costumes, which in turn were controlled by the movements of the persons wearing them. Depending on environmental conditions and body movements, the costumes went from a static expression to activating changes and then changed back to its original expression(Worbin, 2010). Lauren Bowker and the THEUNSEEN company she leads presented a couture capsule collection, 'Air'(2014), which consisted of a garment that responded to heat, moisture and UV radiation, a large heat-responsive sculpture, and wings that reacted to friction and aerodynamics. The leather, beast-like garment was created with Bowker's compound inks and dyes, which responded to seven different parameters in the environment, and allowed a mix of controlled and uncontrolled color changes in the material(Kettley, 2016). Lynsey Calder explored color-changing tutu costumes, entitled 'CodedChromics'(2014). Details of the fabric's geometric pattern were printed in color-changing TC inks and controlled by an 'Arduino Mini' microcontroller programmed to control the costume's phase-changing element. A fluorescent pigment mixed into the TC pigment was activated by UV black light on stage, creating a gradient glow effect as the TC inks were heated. 'CodedChromics' showed how different levels of electrical current affected the color range of the printed pattern(Pailes-Friedman, 2016).

As the third type of smart color change techniques, EL renders a color change by manipulating lights in optical fibres or luminescent materials. Luminex produced a high-tech, fibre optic fabric with RGB LED lights that could emit and change light colors by combining textiles, optics and electronics(Luminous fiber optic, 2015). Some fashion designers have often used LEDs and e-textiles in all three techniques to change the visual expressions of their collections. Hussein Chalayan has often presented transformable fashion designs and has a particular interest in technology using lights, lasers, and crystals. In the 'Readings' show(Spring/Summer 2008), laser lights were beamed through Swarovski crystals, reflecting light from the garment and bouncing it off surrounding mirrors, thus presenting an interplay between the garment being modelled and the audience. As a conspicuous example, in the 'Airborne' show(Autumn/Winter 2007-2008), a dress consisting of 15,600 LEDs combined with crystals, displayed short, abstract films that looked like a digitally animated print design, producing an effect that was both beautiful and beguiling(Clarke & Harris, 2012; Seymour, 2008). Angel Chang has designed for the future with smart fabrics that are sensitive to heat, sunlight, or LEDs, as shown in the 'Spring' (2007), 'Fall'(2007), and 'Spring'(2008) series(Seymour, 2008). CuteCircuit, a wearable technology and interaction design company founded by Francesca Rosella and Ryan Genz, presented an LED evening gown example, called 'GalaxyDress'(2008). It used over 24,000 LEDs of all colors in the world's largest usable color display garment, which also had more than 4,000 Swarovski crystals(Kettley, 2016; Seymour, 2008).

Some examples of dynamic textiles and garments using EL have tried technically and emotionally interactive textiles and garments, networking among users, environments and society. CuteCircuit also demonstrated interactive color- and pattern-changing garments using EL in an emotionally responsive clothing series called 'Skirteleon'(2004), a skirt that reacted to the activity and moods of the wearer. It also created 'KineticDress'(2004/2007), which was embedded with sensors that captured the wearer's movements and interactions with others through the EL embroidery of the dress (Seymour, 2008). As another example of interactive interfaces using LEDs, Barbara Layne created 'Jacket Antics'(2007), which featured unique texts and designs scrolling through the LED arrays on the backs of two garments. The animated clothing displays created new possibilities for dynamic social interaction(Seymour, 2008; Studio subtela). 'Tornado Dress'(2007) was a dynamic, environmental interaction that featured a Mimaki print of a tornado by Mike Hollingshead, with super-bright, white LED embroidery. Depending on the quantity of light that was sensed, different flashing patterns were triggered that were reminiscent of lightning effects that accompany severe weather situations(Seymour, 2008; Studio subtela). Philips Design explored the interaction between

the human body, apparel and the immediate environment through 'The Skin Probe Project'(2006). Using LED projectors and emotional sensing, 'The Bubelle' was a 'blushing' dress that responded to skin contact by illuminating various patterns; it behaved differently depending on who was wearing it, exhibiting completely nonlinear behavior(Quinn, 2002; Seymour, 2008).

From this typology of dynamic color change techniques, we can see that the 'fashionable wearables' mentioned by Seymour(2008) have currently demonstrated great expressive promise and the potential to be amplified through the use of technology. Dynamic textiles and garments that change colors and patterns express retro-reflective and interactive designs that react to user demands. They demonstrated that they could revert to the exact same original condition as the time factor is controlled, and their interactivity ranged from human beings to environments and societies and extended to networks in the hypertext structure. The dynamic garments resulted from compositional elements that generate heat, using TC yarns or inks, PC UVs, or EL LEDs.

2.2. Virtual dynamic patterns in tangible fashion using computational technology

As shown in the examples above, the digital world can provide textiles and garments with variability, and their elements can be changed into completely different substances. Worbin(2010) stated that smart textiles could be seen as a new type of soft hardware, where computer software can influence the textile expression just as intensely as color and form had previously done. As computational technology, including computer graphic software, has become available to both fashion and textile designers, digital aesthetics have provided the inspirations for new design ideas and visual expressions.

When viewing the visual and cultural characteristics of fashion as an everyday lifestyle product and not only as a fashionable art, it is apparent that it needs to be more easily controlled, personalized to the wearers' tastes and connected with others in its dynamic transformation. In particular, to display more customized and various dynamic patterns in fashion, we can create digitalized dynamic patterns using computer graphic software by encoding digital pattern information with computational hardware.

In the late 1970s, the appearance of digital color graphics radically changed image-based industries. Imaging software such as 'Photoshop', 'Illustrator' and 'After Effects' greatly influenced every sector of the art and design fields, enabling professionals and amateurs to manipulate both still and moving images. Added to this were the formidable Internet and the growth of social networks, which have provided an indispensable creative platform for users to communicate and collaborate on a variety of design ideas. In last few years, collaborating with fashion image-makers, some designers have developed a new fashion code with a sophisticated use of digital special effects, using 2D, 3D and moving-image tools to fast-forward us to unimagined lifestyles and future visions(Clarke & Harris, 2012). Thus, the implicit code of virtual dynamic patterns has often emerged with the convergence of analogue design methods and digital image-making processes, as described below.

Integrating LED technology into his 'Airborne'(A/W 2007-8) catwalk, Hussein Chalayan also displayed a digitally animated print design within the garment form to look like the full video of a computer-generated film. Collaborating with a computer graphics operator, Jane Harris concentrated her creative practice on computer graphic visualizations using motion capture. The projected video artwork such as 'Potential Beauty'(2002-3) highlighted this technique in its abstract form, in order to develop relationships between fabrics, garments and the human body through the digital simulation of a garment twisting and turning in space(Clarke & Harris, 2012). Although Harris's digital artwork did not suggest a dynamic pattern, it indicated the possibility of motion and transformation virtual textiles and garments in the future could bear, including the folds and draping of a fabric, not just digitally painted textiles. As another example of the relationship between digital imagery and the human body, Nancy Tilbury, a co-founder and director of Studio XO, developed the 'Digital Skins'(2011) series that explored the extent to which textiles could be programmed to create changeable patterns and to vary colors like a chameleon's skin(Studio Nancy Tilbury, n.d.). A collaboration between the multimedia artist group UVA(United Visual Artists) and Hamish Morrow introduced a virtual print display in his collection called 'Beauty of Technology'(S/S 2004), where sequential 3D flashes of a series of infinite virtual prints were created by digital media and then projected onto the 'blank canvas' of the dress(Clarke & Harris, 2012). Thus, Morrow created a print that was not fixed in time, but rather virtual and ever-changing.

Digital media tools have dramatically altered 2D, 3D and 4D images and empowered them with motion-making and interactive capabilities. Indeed, the aforementioned examples of virtual dynamic fashion have revealed some ground-breaking thinking on the future of digitalized fashion regarding its aesthetic and conceptual qualities that go beyond the usual vision. At the same time, digital media will also lead to creating commercially ambitious and newly personalized fashion products by integrating conventional analogue design processes. In particular, interactively customizable virtual dynamic patterns within fashion garments and accessories have recently appeared in personal portable devices, such as mobile phones, cameras, or glasses.

More recently, through Augmented Reality(AR) technologies,

dynamic patterns have frequently appeared in high-fashion collections, mixing physical and virtual realities. Apparel by Normals (2012) and fashion designer Marga Weinmans(2013), presented virtual garments and generated AR additions of 2D or 3D moving geometric patterns around them, using a mobile application and Google Glass(Apparel by normal, n.d.; Wearable augmented reality, 2013). A fashion designer, Kailu Guan(2016), added virtual layers of 3D shapes and moving patterns to garments, using AR and a mobile application(McGregor, 2016).

Furthermore, some commercial fashion garments have already shown the customizable possibilities of dynamic patterns controlled by mobile applications. CuteCircuit launched the first fully customizable t-shirt, 'Infini T-Shirt'(2012), which features a thin display and a small, battery-powered computer with the ability to display images, animations, tweets, photos, and play music (Special projects, n.d.). Shiftwear Corp.(Shwiftwear, n.d.) produced customizable sneakers containing a screen technology with batteries and sensors by developing the user experience(UI/UX) for the mobile application. SmartPixels(Smart pixels, n.d.) has created live retail environments for fashion brands by projecting moving images onto fashion items, using 3D AR video-mapping technology.

The introduction of new materials and technologies has challenged us to develop new ways of thinking and working to augment the innovative potential of fashion design. As Quinn(2012) mentioned, fashion materials in the future will be more fluid than fixed, responding, changing and adapting to sets of pre-programmed parameters. Dynamic textile patterns will be an essential means of communicating and expressing the wearer's technological tastes in the fashions of the future. Thus, fashion designers need to integrate existing traditional methods with fashion design elements integrated with digital technologies, and further explore them as part of their creative agendas.

3. Digitalized dynamic fashion illustration using motion graphics: Graphical patterns in motion

Digitalized dynamic fashion design permits fashion items to be customized with flexible colors and patterns of both still and moving images, extending the reach of fashion design. For this project, the author intended to present the future potential of a dynamic fashion garment embedded with moving graphical patterns by creating and exhibiting ten digital fashion illustrations of dynamic fabrics that can not only change their overall color but also display complex patterns. The digital illustrations basically focused on the same topic of how to create dynamic garment patterns that visually change over time. However, it also asks the question whether digital media and display technologies integrated into textiles can open new perspectives of flexible and interactive expressions for real-world fashion creations and not just in a virtual space.

Fashion illustration is a visual language to express a fashion message through images, and digital fashion illustration applies digital technology to an analogue fashion illustration. Digital fashion illustration enables unlimited visual expressions and aesthetic effects by providing fashion illustration with movement, variability, interactions, and virtuality through various compositions and multiple repetitions(Kho & Lee, 2017). Its digital image processing capability can extend to 4D animation, called 'time art', that goes beyond 2D and 3D. Therefore, digital fashion illustration could be an appropriate medium to represent dynamic, active, or interactive impressions and optical effects, beyond static images.

3.1. Theme

The author created digital fashion illustrations with the theme of 'psychedelia' to visualize experimental explorations of screen-based, moving graphical patterns. The term 'psychedelia' was given originally to the subculture that used psychedelic drugs often but also refers to psychedelic art or a psychedelic music, reflecting an experience of altered consciousness and hallucinations(Psychedelia, 2016). This project showcased transformable fashion fabrications with surreal visuals, dramatically bright and fluorescent colors, and kaleidoscopic optical and geometric patterns inspired by psychedelic art. In addition, by playing psychedelic music in the exhibition hall, the author intended to convey both visual and auditory psychedelia.

To create the digital fashion illustrations with Frida Kahlo's iconic look in mind, the author was inspired by Etro's S/S 2013 and A/W 2013/14 collections, photographed by Erik Madigan Heck. The accompanying fashion illustrations were created in more abstract and monotonous ways to express impassive and static body images, in contrast with the psychedelic movements of the dynamic patterns within them.

3.2. Technical method

To add the dynamic graphical pattern effects to the digital illustrations, the author tried collaborating with a group of digital graphic designers and motion artists called 'Protobacillus' via the 'Tumblr', a social network service(SNS). As a SNS has been recently a significant platform to communicate and share various artists' ideas and works, fabulous GIF animations by 'Protobacillus' posted to the 'Tumblr' sparked the inspiration for me to create the dynamic graphical patterns for fashion design.

In terms of the technical method, the author used the 'Illustrator' to create the digital fashion illustrations as a first step. Next, the

author took apart the GIF animations(produced by the 'After Effects') in 'Photoshop', and then mapped each fabric image in turn to the parts of the garments and accessories in the digital fashion illustrations through photoshopped collages. Finally, each fashion illustration mapped with the sequential fabric images was composed with a video group and saved as a GIF or rendered as a mp4 file by 'Photoshop'. Thus, the end results were extraordinarily energetic and freshly dynamic graphical patterns.

As exemplified in Sample 1, a static fashion illustration(the default condition) with solid base garments was created using 'Illustrator' as the first step(Fig. 3a). In the second step, different GIF files were used for dynamic fabrics(Fig. 2). The animation files were opened with multiple layers of separate images in 'Photoshop' and had 24 sequential frames that displayed according to the timeline function(Fig. 1a). Based on every sixth frame by 0.24 second of the sequential frames, separate images with different colors and patterns were chosen for the dynamic fabrics. In the third step, the default illustration was replicated ten times. Then, the prepared dynamic fabrics were mapped onto the replicated digital illustrations in various ways. In the fourth step, each static digital fashion illustration containing different fabric patterns was composed to create a video group of the dynamic fashion illustration. The video group was saved as a GIF, or rendered as an mp4 file to be played with QuickTime Player. In the last step, the resulting file was opened and the dynamic digital illustration was finally played (Fig. 3p). By selecting different numbers, order, delay time, and looping options for the animation frames in the timeline panel, the dynamic fashion illustration could present a variety of expressions, with different transition speeds, inversion effects, repetition options, etc.; ten digital illustration frames could therefore transform into nineteen frames(Fig. 1b-1, Fig. 3p). This paper presents only four representative samples out of the ten illustrations, which display different dynamic graphic effects.

3.3. Dynamic digital fashion illustration with four samples

Sample 1(Fig. 3) is a digital fashion illustration that includes dynamic patterns on the back of a t-shirt and a hair accessory. The dynamic patterns in the garment present gradual color changes and animated patterns, which are interchangeable with the patterns in the illustration's background. The dynamic patterns present two

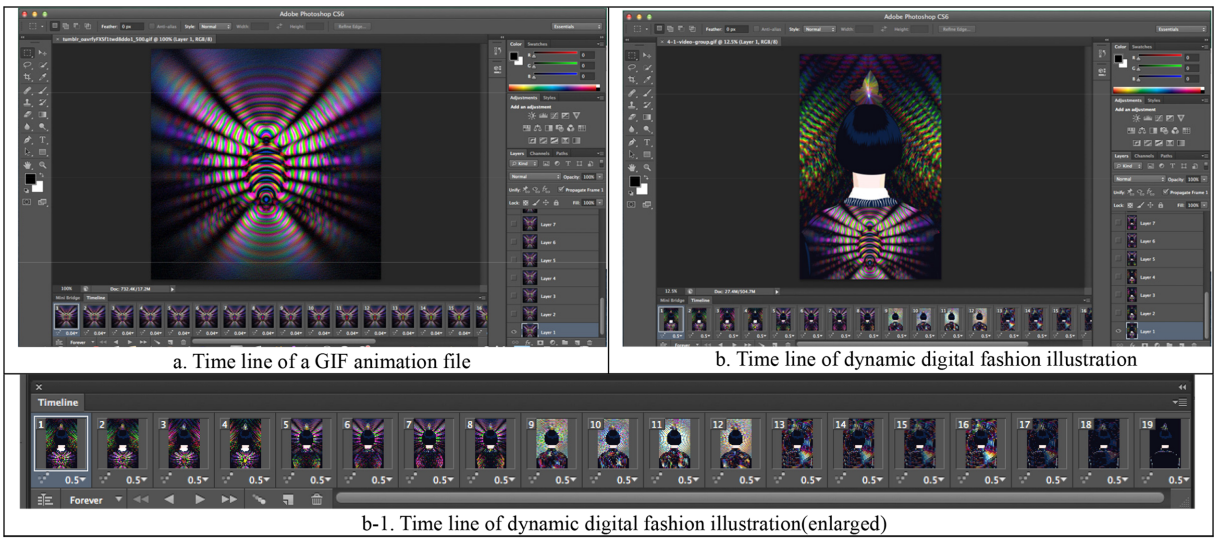

Fig. 1. Production process of a dynamic digital fashion illustration(Sample1).

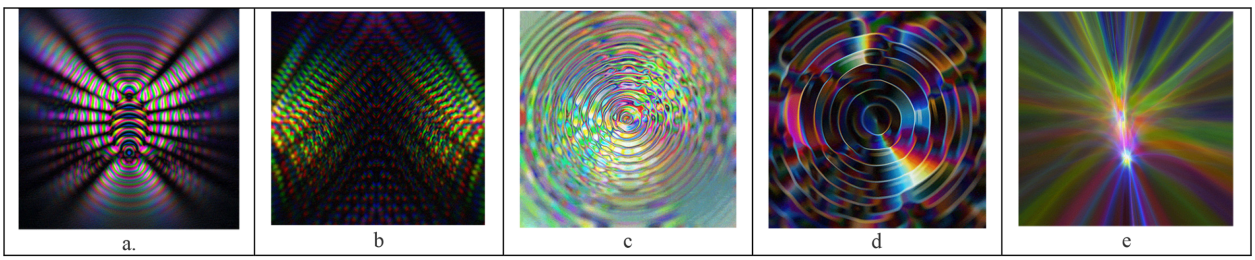

Fig. 2. GIF(hyperlinked) dynamic fabrics(designed by 'Protobacillus').

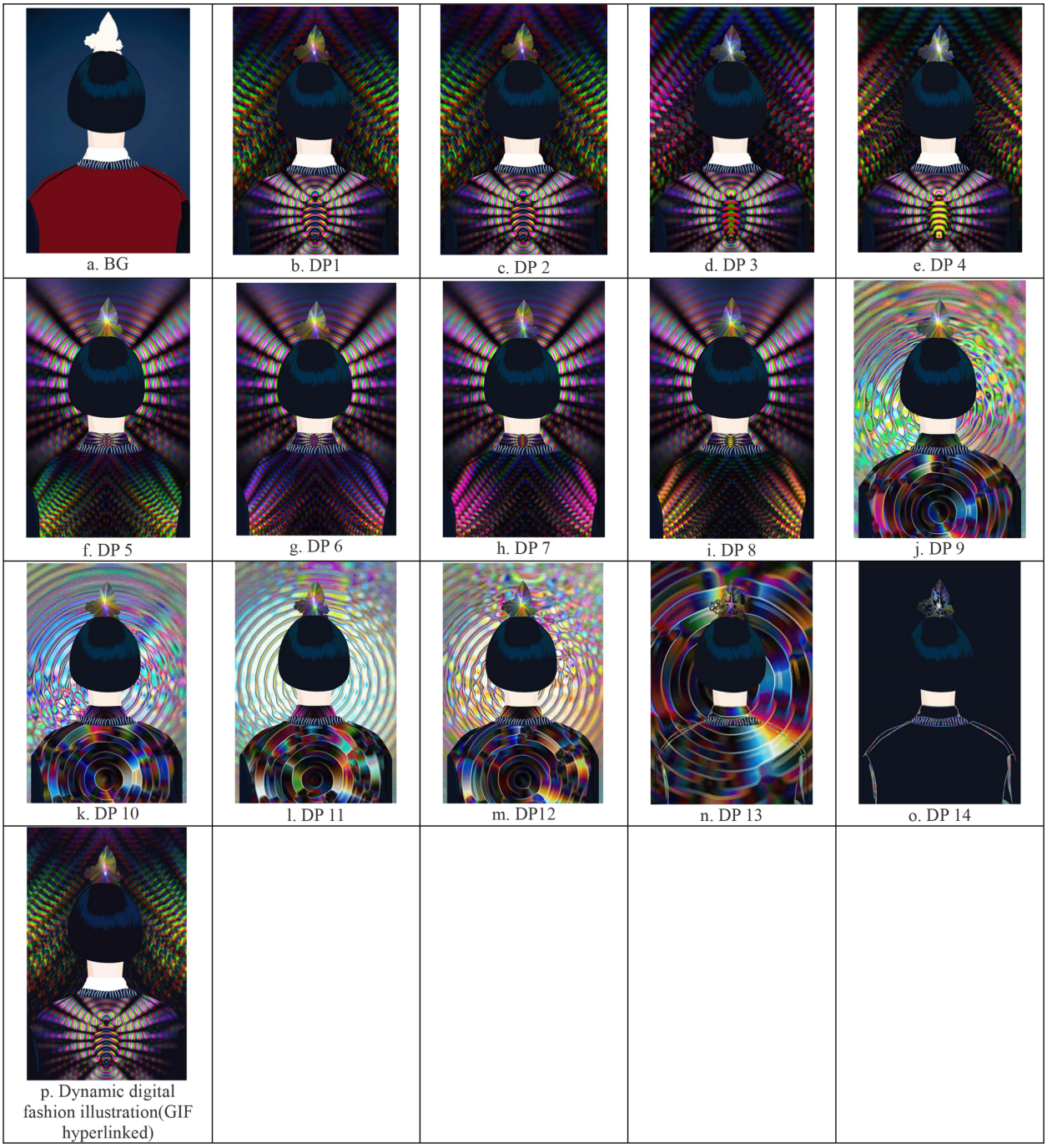

Fig. 3. The base garment(BG) and dynamic patterns(DP) (a t-shirt and an accessory) of Sample 1.

types of radial shapes and concentric circles, which gradually evolve from one shape to another and then back to the original condition using the replay option. The dynamic patterns expand and contract repeatedly, and the fills and the strokes of the objects are exchanged, creating blurring effects between the objects and the background and between fills and strokes. The different expressive effects represent a virtual dynamic fashion design that is interactive to the demands of wearers and environments.

Sample 2(Fig. 4) focuses on the dynamic changes not only in the colors and patterns of fashion objects such as a top and an accessory but also changes in pattern sizes and the various background images. The dynamic geometric patterns in the hair accessory and the sleeve are gradually scaled up and down, while the background changes with vertical, horizontal, and radial shapes displaying in

Fig. 4. BG & DP(a top and an accessory) of Sample 2.

turn. The dynamic garment patterns change in reaction to the background patterns, and the lines between the objects and the background, and between the fills and the strokes are blurred in the dynamic digital illustration.

Sample 3(Fig. 5) adds optical art changes to the dynamic colors and patterns of a dress and a hair accessory. The optical pattern is a spiral that first revolves in the background, then at the top of dress, and lastly throughout the entire dress. This not only creates an additional change in the dynamic patterns but also blurs the lines between the dress and the background. The dynamic patterns of the dress vary in color, form, and size, and the patterns of the hair accessory have an animation that looks like a flower blossom.

The dynamic changes of Sample 4(Fig. 6) begin in the background and then different dynamic patterns appear first in the skirt, then the midriff, and finally in the shoulder of the top, transforming the individual garment pieces into a complete dress. In addition, the dynamic patterns of the background and the garment switch back and forth, presenting surrealistically rotating butterfly motifs and different tones and colors in the botanical imagery. Of particular note are the dynamic changes of Sample 4, which ends with a magical, invisibility effect in a part of the top by adding the same background color to it. This reflects the 'invisibility cloak'(Quinn, 2012), created by scientist Susumu Tachi using technology.

3.4. Results and discussions

From the virtual experiments of dynamic digital fashion illustrations, the author recognized that digital media can provide a myriad of aesthetics and expressions and identified the following

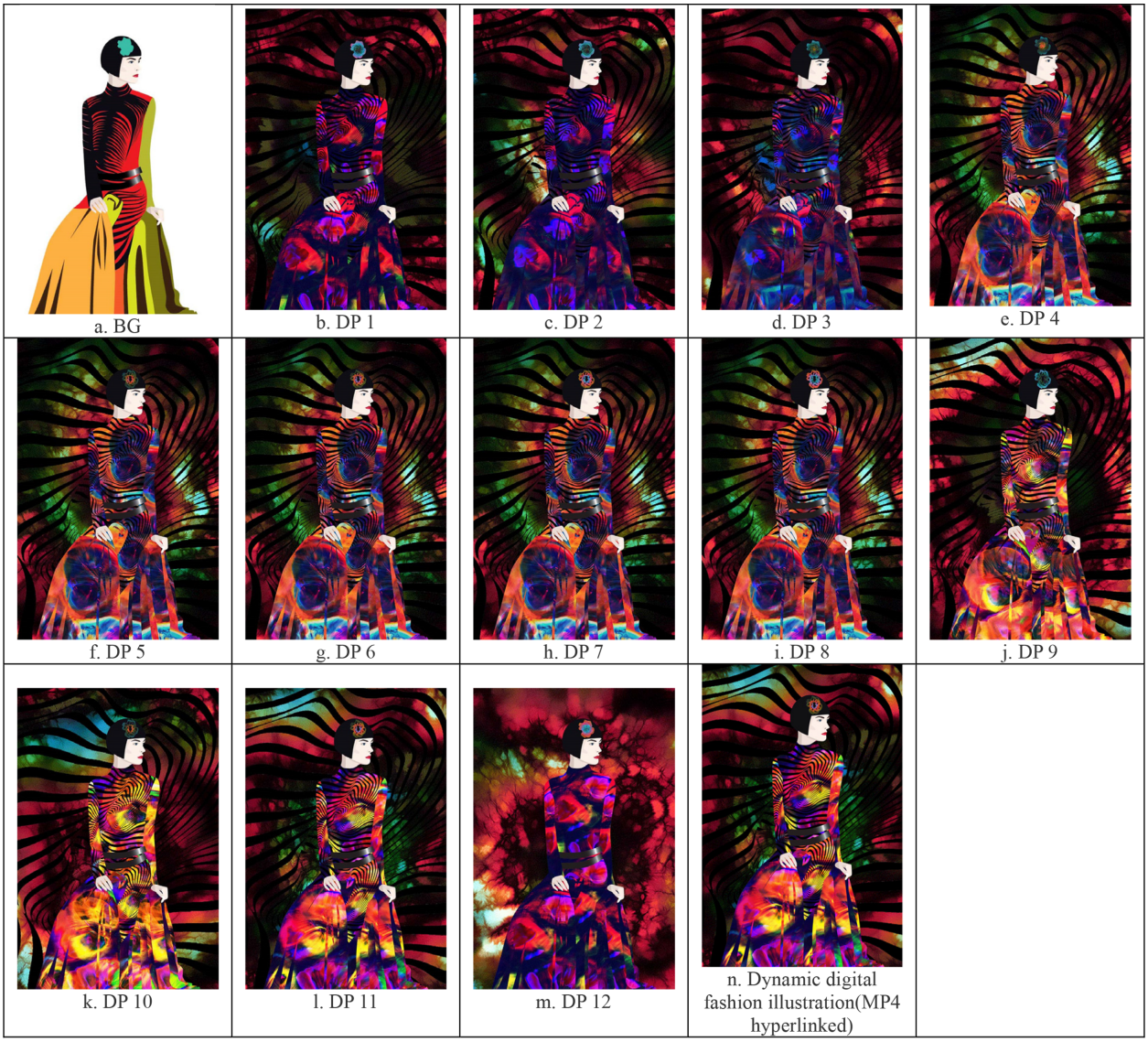

Fig. 5. BG & DG(a dress and an accessory) of Sample 3.

findings.

First, digital dynamic fashion illustrations did not fundamentally characterize 'variability' in the color and patterns in motion but also did demonstrate various expressive effects such as 'composition of different elements', 'multiple duplicability', and 'hyper-reality'. The dynamic graphical patterns of the fashion garments and textile-based accessories and the backgrounds of the digital fashion illustrations continued to present flashy animation and idiosyncratic movement with infinitely changing colors, forms, and sizes. This transformed the design elements into a completely different look with dynamic manifestations.

Every single frame of the dynamic samples resulted from the hybrid composites of different image sources, and all the digital illustration frames were integrated to create a video group. The default illustration, including the base garment, was replicated and different patterns were mapped onto the replicated base images. Some illustration frames in the video group were also replicated to the extent allowed by the digital media data storage capacity, in order to generate various expressions and self-evolving changes. The resulting dynamic digital fashion illustration suggests a virtual reality to the viewer and sometimes also an augmented visualization in a hypertext structure. In addition, when posted to an Internet space, the dynamic work samples could provide a borderless network space and enable a virtual engagement by various participants.

In this regard, Lee(2009) suggested that the main characteristics of digitally based fashion were 'interaction', 'variableness', 'virtuality', 'multiples' and 'hyper-text'. Chun(2011) characterized

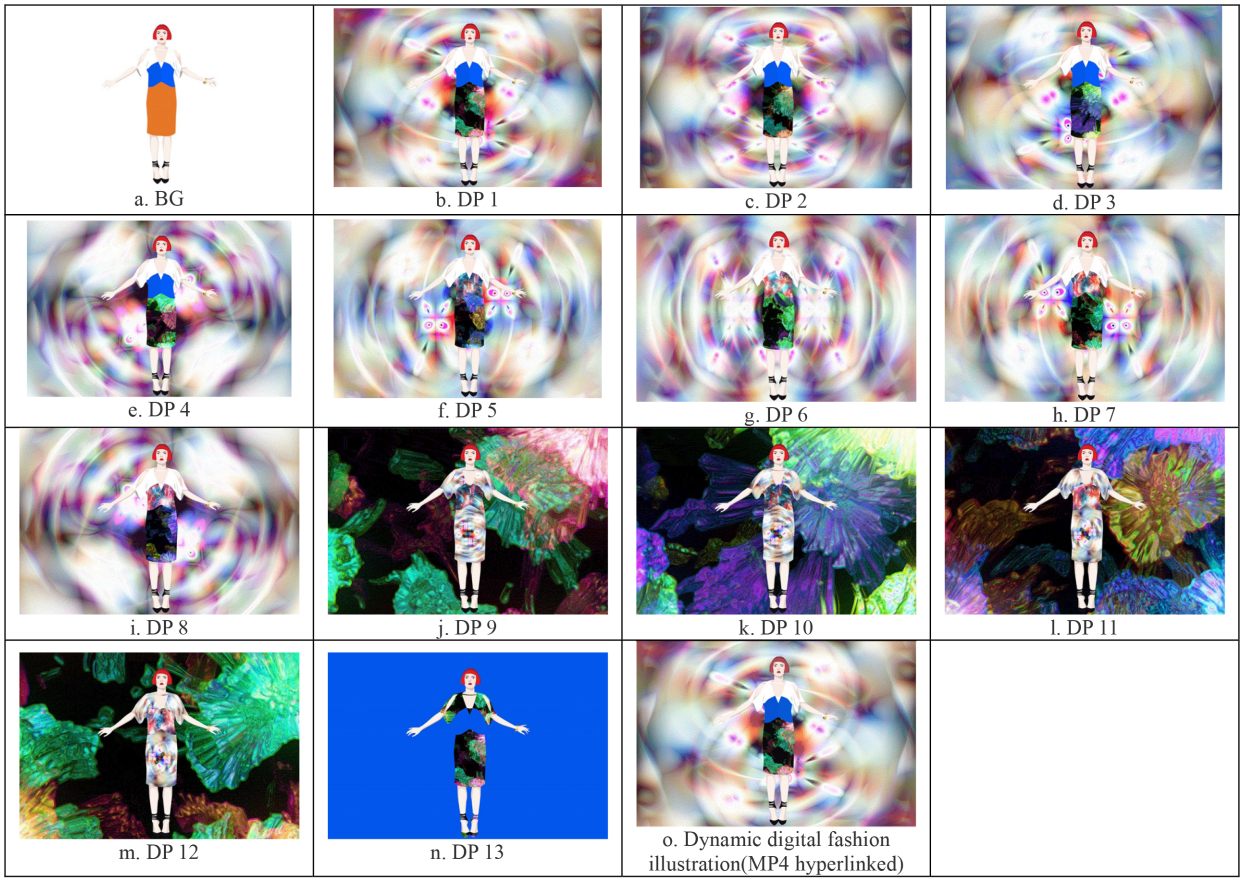

Fig. 6. BG & DP(a top and a skirt) of Sample 4.

digital art and digital fashion as having 'perfect duplicability', 'interactivity', 'networkability', 'variability' and 'compositeness'. Clarke and Harris(2012) said that digital media provide imagined, screen-based scenarios, incorporating imagery that is abstract, hyper-real, macro, time-based, self-generating and fast-evolving. Although the dynamic digital fashion illustrations of this project hardly suggest an interactive effect, one of the significant characteristics of digital art is that they also imply interaction between objects and backgrounds, between more than two objects, or between objects and the viewer by presenting changing dynamic patterns.

Second, the base garment that represented the default condition for the dynamic patterns in the digital experiment was an important element for the visual changes in its colors and patterns. The base garment had plain colors that were ready to be mapped with different dynamic patterns. If the dynamic patterns were to be interactively integrated with digital devices, then virtual, dynamic fashion design, including transformable logos or typography in addition to the different colors and patterns, would lead innumerable styles created from the base garment, and might make its users experience a Virtual Reality(VR). As such, considering the base garment's form and style as a generic object could provide fashion designers with a new agenda. Furthermore, the participants in the VR space could become designers or creators by manipulating personalised dynamic patterns. Farren and Hutchison(2004) stated that the key reason the base garment concept is so important is because it allows an extension of what people are already doing with fashion and garments - making choices about what they wear, how they appear, and what that appearance communicates to other people.

Third, the possibility of dynamic graphical patterns integrated into the base garment might enable the concept of a sustainable and ultimate garment, which might generate a new fashion norm where a single garment functions as multiple garments. Farrer(2011) has already verified that transformable garments could be directly connected to the sustainable practices of consumers through design versatility. In the dynamic digital fashion illustrations, one base garment could be duplicated and transformed into multiple garment designs with different colors and patterns. The ultimate garment, which could be rechargeable and changeable in the virtual world could potentially reduce waste and transform current fashion norms with their seasonal cycles and trends(Mackey et al., 2017).

Fourth, the notion of time in the digital dynamic fashion illus-

tration looked to be continually cyclic and iterative. When motion was integrated into the static illustration, the element of time was introduced to 4D animations of dynamic fashion garments using the timeline function of the software. The dynamic garments changed from one expression to another or several different expressions - from flamboyant to dull colors and from complicated to simple patterns - and then finally returned back to their initial condition. This means that whenever a designer and a user want to go back to the initial garment design, they could retrieve the initial conditions and original expressions of their own garments without wearing them out. Therefore, the element of time in the digital landscape appeared to yield unlimited extensions through an infinite number of parts and repetitions.

4. Conclusions

This study proposed that computer graphics and digital imaging technologies integrated into fashion could virtually create eye-catching and futuristic dynamic fashion designs that can change their colors and patterns and can be customized by the wearers or users. The active wearers or users would be able to download the dynamic fashion garments to try them on the new digital garments and sometimes create their own fashion designs in both the virtual and tangible worlds by controlling the dynamic patterns with digital technology.

The project that produced the dynamic digital fashion illustrations presented in this study has several limitations. The dynamic garments and textile-based accessories did not provide a responsive and interactive technical interface to the users. In addition, the manufacturing of the dynamic textiles and garments and the realisation of their social functions in a real world still remain as an inevitable future agenda. These limitations lead us to more possibilities for digitalized dynamic fashion design, which are avenues for future studies in both the virtual and physical worlds.

First, further development of virtual dynamic fashion designs using computer graphics and digital applications will go beyond enabling simple interaction between consumers and the virtual garments. These future consumers or users will be able to try on dynamic textiles and garments available from virtual wardrobes in everyday life. Mackey et al.(2017)'s study has provided an insightful example of interaction between virtual fashion garments and digital expression using a chroma key smartphone application. However, new digital applications and innovative software still needs to be developed to provide a myriad of digital content and functions that are realistic enough to be commonly used in the daily online communities. In the virtual or hyper-real realm, future consumers or users will be able to select still or dynamic fashion garments and accessories and make new combinations out of stored designs that are infinitely changeable and diverse. They will be able to create their own fits and styles for the identities they want to express, which sometimes might include digital displays for virtual communities using VR/AR technologies.

Next, tangible dynamic fashion garments merged with the virtual dynamic patterns using digital imaging technology will be able to foster customizable and interactive fashion design in the real world. The dynamic fashion design of tangible items will increasingly evolve beyond attaching a flexible computer screen to a t-shirt or sneakers, to other directions that enable different types of fashion items with many virtual dynamic capabilities, not to mention its physical functions. Digitalized dynamic patterns that can be downloaded and customized to tangible base garments might look like perfectly natural 3D effects as if they were an original part of the garment. They would be able to change colors, sizes, and types of dynamic patterns, both static and moving as if they were alive.

In addition to development of the design of both tangible and virtual dynamic fashion garments, there is the aspect of sociological and cultural acceptance of the garments. While early wearable technologies that provided solutions for wearing computational devices and the subsequent 'fashionable wearables'(Seymour, 2008) provided great expressive potential through the use of technology, the currently evolving third waves and challenges in the digital field all converge on enhancing 'fashiontech'(Tomico et al., 2017). These are fashionable and wearable interactions aimed at offering aesthetic resonance and social coherence to the user. As there have been many studies on the social significance of fashion combined with digital technology(Devendorf et al., 2016; Dunne et al., 2014; Farren & Hutchison, 2004; Mackey et al., 2017; Tomico et al., 2017), qualitative/quantitative investigations using consumer surveys about both virtual and tangible dynamic fashion design will be needed. These should be implemented through social media platforms or by targeting specific demographics in order to arrive at compromises for the social/cultural gaps between traditional textiles and garments and dynamic ones that incorporate new digital technology.

Lastly, consumer research about digitalized dynamic fashion design will be inversely connected to the methodological transitions in the fashion designers' creative processes and practices around integrating dynamic graphical patterns into garment designs. Virtual collaborations via inter-net platforms will be also prevalent for various artists and designers to share, communicate, and create their ideas. In turn, the new approaches for dynamic fashion design with digital imaging technology will also have an influence on digital creativity education for a new generation of fashion designers.

Dynamic fashion design might bring about a radical change in

the concept of future fashion as a moment in time. With the emerging advances in digital technology that will continue for the foreseeable future, norms of time and space will be continuously shifting and evolving, challenging the current state of fashion and changing design and manufacturing methods.

Acknowledgement

This research was financially supported by Hansung University. The author would like to thank the Protobacillus group for sharing their artworks.

References

'Apparel by normal'. (n.d.). Retrieved July 1, 2018, from http://mixtur.es/apparel/

Berkenwald, M. (2001). Frame and screen in painting in the digital era. *Digital Creativity*, *12*(3), 184-186. doi:10.1076/digc.12.3.184.3230

Berzowska, J. (2005). Electronic textiles: Wearable computers, reactive fashion, and soft computation. *Textile: The Journal of Cloth and Culture*, *3*(1), 58-75. doi:10.2752/147597505778052639.

Chun, J. H. (2011). A review of the characteristics of digital art expressed in contemporary fashion. *International Journal of Fashion Design*, *Technology and Education*, *4*(3), 161-171. doi:10.1080/17543266.2011.585475

Clarke, S. E. B., & Harris, J. (2012). *Digital visions for fashion and textiles: Made in Code*. London: Thames and Hudson.

Devendorf, L., Lo, J., Howell, N., Lee, J. L., Gong, N. W., Karagozler, M. E., ... & Ryokai, K. (2016, May). I don't want to wear a screen: probing perceptions of and possibilities for dynamic displays on clothing. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 6028-6039). ACM. doi:10.1145/2858036.2858192

Dunne, L. E., Profita, H., Zeagler, C., Clawson, J., Gilliland, S., Do, E. Y. L., & Budd, J. (2014). The social comfort of wearable technology and gestural interaction. *Proceedings of the 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 4159-4162. Hoboken, NJ: IEEE. doi:10.1109/EMBC.2014.6944540

Farren, A., & Hutchison, A. (2004). Digital clothes: Active, dynamic, and virtual textiles and garments. *Textile*, *2*(3), 290-307. doi:10.2752/147597504778052676

Farrer, J. (2011). Remediation: Discussing fashion textiles sustainability. In A. Gwilt and T. Rissanen (Eds.) *Shaping Sus- tainable Fashion: Changing the Way We Make and Us Clothes* (pp.19-34). London: Earthscan.

Kettley, S. (2016). *Designing with Smart Textiles.* 56 vols. London: Bloomsbury.

Kho, J. M., & Lee, J. H. (2017). The concept of temporal types and expressive characteristics in digital fashion illustration - Focused on comparison of digital painting and digital fashion illustration -. *Journal of Fashion Design*, *17*(2), 111-125. doi:10.18652/2017.17.2.7

Lee, J. H. (2009). A study of simulacre expression in fashion illustrations, using lenticular technique. *Journal of the Korean Society of Costume*, *59*(8), 152-165.

'Luminous fiber optic wedding dress'. (2015, November 13). Retrieved July 1, 2018, from http://www.luminous-clothing.com/NewsDetail/Luminous-fiber-optic-wedding-dress-.-_135551.html

Mackey, A., Wakkary, R., Wensveen, S., & Tomico, O. (2017). 'Can I Wear This?' blending clothing and digital expression by wearing dynamic fabric. *International Journal of Design*, *11*(3), 51-65.

McGregor, R. (2016, September 23). Augmented reality. *LSN global.* Retrieved July 1, 2018, from https://www.lsnglobal.com/news/article/20161/augmented-reality

Orth, M. (2004). Interactive interfaces. In S. Seymour (Ed.), *Fashionable Technology* (pp. 55-79). New York: Springer Wien.

Pailes-Friedman, R. (2016). *Smart textiles for designers: Inventing the future of fabrics* (2nd ed.). London: Laurence King.

Post, E. R., Orth, M., Russo, P. R., & Gershenfeld, N. (2000). E-broidery: Design and fabrication of textile-based computing. *IBM Systems Journal*, *39*(3.4), 840-860.

Quinn, B. (2012). *Fashion futures*. London: Merrell.

'Psychedelia'. (2016, July). Retrieved July 1, 2018, https://en.wikipedia.org/wiki/Psychedelia

Robertson, S., Taylor, S., Christie, R., Fletcher, J., & Rossini, L. (2008). Designing with a responsive colour palette: The development of colour and pattern changing products. *Advances in Science and Technology*, *60*, 26-31. doi:10.4028/www.scientific.net/AST.60.26

Seymour, S. (2008). *Fashionable technology: The intersection of design, fashion, science, and technology*. New York: Springer.

'Smart pixels'. (n.d.). Retrieved July 1, 2018, from http://www.smartpixels.fr/

'Special projects'. (n.d.). Retrieved June 25, 2018, from http://cutecircuit.com/special-projects/

'Studio Nancy Tilbury'. (n.d.). Retrieved July 1, 2018, from https://fashionphreaking.wordpress.com/studio-nancy-tilbury/

'Studio subtela'. (n.d.). Retrieved June 25, 2018, from http://subtela.hexagram.ca

'Swiftwear'. (n.d.). Retrieved July 1, 2018, from www.shiftwear.com

Tomico, O., Hallnäs, L., Liang, R. H., & Wensveen, S. A. (2017). Towards a next wave of wearable and fashionable interactions. *International Journal of Design*, *11*(3), 1-6.

'Wearable augmented reality'. (2013, Februray 9). *AugmentNL.* Retrieved July 1, 2018, from http://augmentnl.com/hyperfabric/

Worbin, L. (2010). *Designing dynamic textile patterns*. Borås: University of Borås. https://www.diva-portal.org/smash/get/diva2:876942/FULLTEXT01.pdf

(Received 20 March, 2019; 1st Revised 16 April, 2019; 2nd Revised 16 May, 2019, Accepted 24 May, 2019)