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A Study on 3D Virtual Clothing Fashion Design Applying Frank Stella Painting

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virtual clothing,
fashion design,
fashion and art

Abstract

This study aimed to develop a modern textile design based on the formability of Frank Stella's paintings and to develop and present a fashion design that combines modern sensibility as a 3D virtual clothing program. The formative characteristics of Frank Stella's work were 'unity due to regular stripes', 'asymmetry due to geometric surface division', and 'decorabilitydue to colorful use'. Based on this, costume patterns and textiles based on Frank Stella's paintings were developed and six 3D virtual fashion design works were produced. The conclusion was as follows. First, it was confirmed that Frank Stella's work has a very wide range of applications to fashion products as abstract expression and minimal simplicity coexist visually. Second, various colors and forms of Frank Stella's paintings could be developed using textiles with visual formability, and originality as a fashion work applied with paintings could be maximized. Third, the development of 3D fashion using virtual programs had the ease of time efficiency, cost reduction, and spatiotemporal expansion of work processing compared to the actual costume production process. In addition, the simulation of 3D virtual wear made it easy to modify and recover the position of the textile to be applied to the costume and create a new design in the process of transforming the position of various textiles. It is expected that this study results will be used as basic data for the future conversion content industry in the painting and fashion industries.

Ⅰ. Introduction

Fashion transcends the boundaries of all genres and areas across society and culture and mutually influences them, and designers sometimes create new genres through collaboration with other areas of art. In order to satisfy the needs of consumers who value individuality, modern fashion is being combined with fine arts such as sculpture, architecture, and painting in various forms. In particular, grafting with painting based on artistic formative beauty is becoming a means of expression of creative fashion that goes beyond the original work and discovers new forms of artistic value.

Frank Stella(born 1936) is an American abstract expressionist who has contributed to expanding the realm of painting, ranging from organized to lyrical, and has pursued constant change through the use of experimental and innovative materials. His work appeared sensibly through a rich form of expression by introducing color and decorative patterns. Looking at previous studies related to Frank Stella, Lee and Lee(2003) studied the expansion of the formative area of Stella's works and the impact on the landscape architecture, Lee(2008) studied the characteristic aspects and the world of works in Stella's works. Hong(2016) continues to research on Frank Stella, such as developing handbag designs based on works from the early flat painting period among Stella's works, but research on fashion design incorporating Frank Stella's paintings is insufficient.

On the other hand, the 3D virtual clothing program is a groundbreaking 3D three-dimensional clothing system manufactured by combining IT technology with fashion, and is mainly used in the design development, pattern development, and sample development process. Since the product development process time is shortened and the appearance evaluation is similar to the actual clothes, it is highly efficient and is being expanded and used in the fashion industry(Seo & Kim, 2021).

At a time when art and fashion need to be combined in line with this digitized era, research that reflects Frank Stella's expressive characteristics on the border between abstract expressionism and planar minimalism can be very meaningful in that it inspires art in the field of fashion design that requires infinite inspiration. Therefore, the purpose of this study is to develop a modern textile design based on the formative characteristics of Frank Stella's painting and develop and present an original 3D fashion design using a virtual clothing program. It will be able to satisfy this by presenting an original design that gives the artistic value of painting to modern fashion that requires expression of sensibility and is of research value in that it shows the infinite expression potential of fashion design.

As a research method, a theoretical study was conducted to examine the background of the formation of the work and the world of his work through literature research, and articles and image data were collected and reviewed through the website and the Internet. In addition, by analyzing fashion cases applied with paintings and analyzing the current status of the 3D digital fashion industry, the foundation for developing 3D virtual clothes was laid. The scope of the study was selected as the work of Frank Stella's period of flat painting(1958-1970). The reason was that after the 1970s, various types of sculptures were combined to create relief paintings, not flat works, and it was judged that it would be more effective to expand the scope of expression by reflecting the formability of works in the period of flat painting that maximized two-dimensional flatness. As an empirical method for the development of the work, 75 works from the period of flat painting that clearly shows modernist pictorial characteristics during Frank Stella's work activities were selected to analyze the formative characteristics. Based on this, the motif was extracted using Adobe Illustrator from Frank Stella's work, and a textile design was developed by newly combining and applying it. By applying the developed texture, six 3D virtual clothes fashion using the CLO 3D program were presented.

Ⅱ. Theoretical Background

1. Frank Stella

1) The World of Frank Stella's Works

Frank Stella, the representative of minimal art in the 1960s, is an American painter who presented experimental paintings. Frank Stella began to attract attention with "Black Striped Painting" when he participated in the "16 Americans" exhibition at the Museum of Modern Art in New York in December 1959(Hong, 2016). With the principle of so-called non-relational composition as opposed to the European-style composition that considers the balance of left and right top and bottom, the direction of painting was suggested in the direction of excluding illusionism from the screen and restoring the physical properties of painting(Kim, 1998). Stella's world of work, which begins in this way, can be classified into four categories by William Rubin(Rubin, 1970) : Stripes and Shaft Canvas period (1958-1965), Irregular Polygons and Protrators series period(1965-1970), Relief-painting period (1970 -1975), and Sculpture-painting period (1976-present). Stripe and Shaped Canvas periods pursued a single image with strict flat painting. It was a time when we tried to overcome the limitations of modern painting without departing from flatness and media limitations by creating a so-called shape canvas concept that matches the outer shape of the picture frame and the depicted pattern on the screen(Lee, 2008). Later, the Aluminum series (1960-1961) was the first shaft canvas work created by prioritizing the shape of the canvas itself and then removing the edge of the frame based on the expression of movement filled within it(Yang, 2001). De la nada Vida a la nada Muerte(1965) is a work that stands out with visual illusions suggesting irregularities on its surface and can be said to have something in common with op-art in the mid-1960s. The period of the Irregular Polygon and Protractor series is a significant transition from the period of striped paintings. In the Irregular Polygon series of 1966, he tried to contrast the geometrical form of color planes by breaking away from the left-right symmetrical achromatic stripes. Michael Fried sees this period as the time when the ambiguity of Stella's pictorial space appeared as the greatest characteristic(Rubin, 1970). The Protractor series(1967), which was released soon after, was Frank Stella's own color mixing and use, and as a result, this series became the most spectacular and commercially successful among the works up to that time(Kang, 1995). The Saskatchewan series(1968-1969) is a work consisting of a rectangular background and curved images, and it can be said that Frank Stella's sense of color is well displayed.

Frank Stella's Relief-painting period began in the Polish Village series(1971-1973), published after a large-scale 1970 retrospective at the Museum of Modern Art in New York. The series consists of flat collages using materials such as felt and canvas, low relief with wooden compressed cardboard or masonite for support, and high relief with cardboard covered with sheet(Kang, 1995). In the Exotic Birds series(1976-1980), a collection of aluminum shapes appeared to protrude from the wall, and elaborate curves, spirals, and ring-shaped sculptures were presented in spatial paintings rather than flat paintings using colorful colors. Since then, the work has been mainly composed of a pictorial screen based on a baroque sense of space and colorful colors, making it a transition to the 1970s(Rubin, 1970). Indian Birds series(1976-1978) used colorful colors, shiny surfaces, and grille to showcase three-dimensional works that are difficult to call paintings. The 1980s Circuit series (1981-1984) and Shards series(1982-83) demonstrated dynamic freedom, agility, and energy in the production process itself by improvising works using various industrial materials.

Frank Stella's tendency to work in the period of Sculpture-painting(1990-present) first combined metal and cast parts of the found object in 1990 to showcase completely three-dimensional independent relief works, and in 1992, unique sculptures that completely faded(Hong, 2016). His sculpture work, which deviates from his paintings so far, can be interpreted as pursuing a more expanded space through three-dimensional objects, and in the 2000s, it changed to a structural character closer to architecture(Hong, 2016). He participates in parks and art design and suggests the introduction of pictorial spaces.

2) The Formative Characteristics of Frank Stella's Painting

Frank Stella said that his paintings are 'what you see is what you see'. It was emphasized that painting is an object as it is seen, nothing more or less than what is drawn on the surface of the canvas, and an object as a meaning without any other hidden meaning(Hong, 2016). It can be said that Frank Stella's work resulted in the painting itself becoming an object. Among these Frank Stella works, I would like to examine the formability of the work, focusing on the period of flat painting, which pursued free change in flat painting under the influence of abstract expressionism. Among William Rubin's four periodical classifications, the Strip and Shaft Canvas period(1958－1965), and the Irregular Polygons and the period of the Protracter series(1965－1970) were classified as the period of flat painting. This is the period when Frank Stella experimented with the limitations of form enough to recall(Rubin, 1970) that it was a "great leap in his painting development," and it can be said that Frank Stella's pictorial characteristics based on modernism are well illustrated. So in this paper, Frank Stella's according to the characteristics of the flat painting period(1958-1970), formativeness was analyzed focusing on lines, planes, and colors by dividing it into early, middle, and late periods.

(1) Line

The characteristic of the lines of early period is that painting is composed of only thin and parallel repetitive stripes. During the Black Stripes period, about 20 works consisting of vertical, horizontal, and diagonal lines were produced using black stripes as motifs(Figure 1). In these works, the surface characteristics of black paint give a visual effect as if white stripes were repeatedly formed. The Black Stripes series consisted of two ways: a line shaped like a canvas repeated toward the center, and the stripes encountered four sides of the screen square or at right angles. In the Aluminum series, the stripe itself is configured as a painting(Figure 2), and in the Copper series, the bent parts of each stripe are visually connected to form a rhythmic pattern, showing a sense of movement that spreads. The Notched V series is a shaped canvas made of stripes based on the shape of a "V". In the Running V series developed here, the pattern of bending is shown as a sense of movement. The Moroccan series, and the Persian series consist of thick lines using various colors, consistent with the shape of the canvas, but with short lines(Figure 3). Changes in striped paintings appear in the late Irregular Polygonal series, and the repeated stripes disappeared and the work was constructed using a wide color plane. Two colored surfaces of different sizes are surrounded by thick colored bands and are adjacent or juxtaposed to form a contrast. It presented an open, broad, and original work in a different way from previous works that pursued strict geometry.

(2) Plane

Both the early and late periods have flatness, and it is a large-sized work using a shaped canvas. The frame of the canvas was removed, and the painting was constructed to protrude from the wall like a relief. Plane can be classified into symmetrical and asymmetrical characteristics, and in the early days, stripes were arranged in a square canvas, but during the Shaped canvas period, simple repetitive shapes in the canvas were matched with the canvas's border or attempts were made to transform it. In Frank Stella's work, the plane has a horizontally, vertically, and diagonally symmetrical shape. It was the Aluminum series that used deformed canvas for the first time, and the Copper series showed various shapes such as ㄱ, ㄴ, T, 凸, 凹, and + shape(Figure 2). Through this, it can be said that the canvas has developed into an independent geometric form out of the traditional square frame. In the Purple series, various forms such as triangles, pentagons, hexagons, and octagons were reflected in the design of eight works, and the center was developed into an empty form. The mid-term Dartmouth series, the Seagulls series, the Running V series, and the Persian series showed attempts to produce various forms, either inverted or using a single unit(Figure 4). Since then, the Irregular Polygonal series in the late period shows an asymmetrical shape as the image and the shape of the canvas do not match(Figure 5). From this period, the

concept of the Shaped Canvas changed, showing works that did not match the support and pattern. In the Protractor series consisting of various colors and shapes, it seems to be symmetrical to the left and right around the circle, but in fact, it can be seen that the asymmetry is maintained through color changes in each part.

(3) Colors

Frank Stella's Black series had a natural sparkle effect as black enamel paint seeped into the soft canvas(Figure 1). Black paintings produced surface effects through various light reflections on the surface where the texture of the paint itself was felt, and later a series of monochromatic stripes was presented for a while. In the Aluminum series, metallic aluminum paint was used, and with this as a starting point, works using copper and purple metallic paint were created. In the Dartmouth series, bronze metallic paints and metallic paints such as lead, and zinc are used to express cold and material surfaces. Later, in the Benjamin Moore series, alkyd colors were used to display canvases composed of single colors in a complex arrangement. In the middle period, multiple colors were used, but in the Moroccan series, and Persia series, various colors were limitedly used and arranged without overlapping. Afterwards, in the Irregular Polygon series, colors were marked with magic markers, and colors were used so that there were no more than six. This series is not metallic paint, but monochrome with vivid shapes, but it is characterized by the use of paints with different textures such as day-glo color, enamel, and epoxy. The Protractor series and Saskatchewan series show decorativeness by showing colorful colors in complex patterns(Figure 6).

In this way, it was possible to confirm the changes in lines, plane, and colors from the early to the late period of Frank Stella's flat painting. In the early days, it showed a simple form of repeating single-colored thin stripes on the Shaped Canvas, and in the mid-term, it is characterized by various combinations of colors and

Figure 1. *Frank Stella, Morro Castle, 1958*
(www.artsy.net)

Figure 2. *Frank Stella, Six Mile Bottom, 1960*
(www.tate.org.uk)

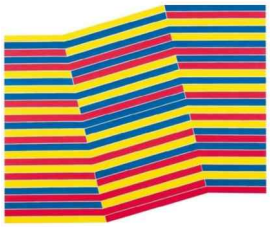


Figure 3. *Frank Stella, Bam, 1965*
(Rubin, 1986, p.250)

Figure 4. *Frank Stella, Empress of India, 1965*
(www.moma.org)

Figure 5. *Frank Stella, Chocorua IV, 1966*
(www.artsy.net)

Figure 6. *Fank Stella, Hagmatana III, 1967*
(www.artsy.net)

regular deformation or movement in the form. Later, in the latter part, it was possible to confirm the characteristics of using asymmetric shapes and colorful colors. The table summarizing the formability of Frank Stella's painting is as follows(Table 1).

2. Modern Fashion Design Using Painting

In modern fashion, there are many examples of designs with the motif of painting works. In this paper, contemporary fashion design cases that applied painting were classified into three types, which could be divided into designs that reproduce the original form of paintings, designs that transformed paintings, and collaboration designs with painting artists.

The original reproduction design of the painting work was expressed in fashion as it is without transformation of the painting, and it was designed so that the painting could be seen on the entire costume using mainly digital printing. Figure 7 is a cocktail dress released by Yves Saint Laurent in 1965, and was designed with inspiration from the work of abstract artist Piet Mondrian(Figure 8). Since then, Yves Saint Laurent has also presented works inspired by the works of Pop artist Tom Wesselman, who used simple and bold shapes and colors, and the works of Impressionist and Post-Impressionist styles such as Cubist painters Georges Braque, Claude Monet, and Vincent Van Gogh. In the spring of 2012, Rodate reinterpreted the landscape expressed in Van Gogh's work as a fashion. A dress work was presented that reproduced the whirlpool of the painting "The Starry Night" as it was in its original form(Figure 9 - 10). The sleeves and waist of the top are draped to express Van Gogh's whirlpool in a more three-dimensional way.

The design that transformed the painting work was found to be an outfit that the designer simplified the painting, expressed parts of the painting in succession, and recreated with new patterns with new inspiration from painting. At the 2012 S/S collection, Etro presented a top and skirt in Figure 11, 12 that applied the

Table 1. *The Formativeness of Frank Stella's Flat Paintings*

Division	Characteristic				Formativeness
	Early	Middle	Late		
Line	· Parallel · Vertical, Horizontal, Oblique · Repetitive · Contouring with Thick Lines · Simple Composition	· Short Color Band · Repetitive · Arranged in a Distorted Form	· Adjacent · Juxtaposition · Originality	⇨	Unity due to Regular Stripes
Plane	· Horizontal Symmetry · Vertical Symmetry · Diagonal Symmetry	· Inversion · Movement · Repetition of Units	· Asymmetrical Canvas Shape · Image Asymmetry · Asymmetry of Color · Inconsistency between Canvas and Image	⇨	Asymmetry due to Geometric Surface Division
Colors	· Black · Aluminum, Copper, Zinc, Lead Metallic Purple · Alkyd Solid Color · Simple Color Contrast	· Variety of Alkyd Colors	· Various Monochrome Colors · Day-glo Color · Epoxy, Enamel	⇨	Decorability due to Colorful Use

paintings of futuristic artist Fortunato DePero (Rolflethenstrom, 2011). It is designed to be a visual point that stands out more in contrast to the black color by using some intense colored paintings on the neckline and the top of the skirt.

The collaboration design with painting artists appears in the form of designers and artists working together from the item planning stage to present their works. Maison Valentino presented the Haute Couture 21FW fashion show "VAELTNINO DES ATELIERS" at the Venice Biennale. Pierpaolo Piccioli thought that if fashion had haute couture, art had painting. So, especially this season, Valentino collaborated with 17 contemporary artists selected with curators and produced dresses inspired by artists' art works(Newspic, 2021). Figure 13 is a painting by Italian artist Benny Boseto, who worked directly with the atelier to insert some of her work into the dress(Figure 14). As such, painting and fashion have been trying to exchange in various ways while sharing the same context as the same art category, and it has been confirmed that fashion designers have been expressing paintings by printing them or using them as patterns for a long time. The connection between painting and fashion is being attempted in various ways, and as a cultural flow, it is expected to expand and progress in more diverse aspects in the future.

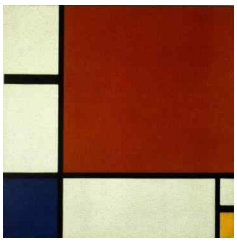


Figure 7. *Piet Mondrian, Composition II in Red, Blue and Yellow, 1930*
(www.piet-mondrian.org)

Figure 8. *Yves Saint Laurent, Short Cocktail Dress, 1965 F/W*
(www.artsy.net)

Figure 9. *Vincent Van Gogh, The Starry Night, 1889*
(www.vincentvangogh.org)

Figure 10. *Rodarte, 2012 S/S*
(multiplefashiondisorder.wordpress.com)

Figure 11. *Fortunato Depero, Festa dellasedia, 1927*
(eightartgallery.wordpress.com)

Figure 12. *Etro, 2012 S/S*
(eightartgallery.wordpress.com)

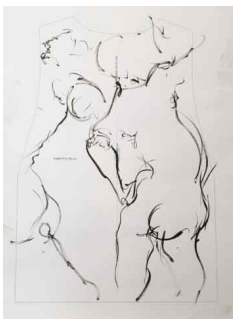


Figure 13. *Benni Bosetto*
(http://gagosian.com)

Figure 14. *Valentino Haute Couture 2021 F/W*
(http://m.newspic.kr)

3. 3D Virtual Clothing

3D digital technology used in the fashion industry can be classified into 3D virtual costume simulation, digital fashion design, smart shopping mall operation and augmentation technology(Shin, 2021). In particular, the 3D virtual clothing program is a groundbreaking 3D clothing system produced by combining IT technology and fashion. It has been expanded and used in the fashion industry by streamlining the development process, such as reducing production time and sample cost(Suh, 2021). Currently, in the process of developing clothing products, there are many variables such as various body types and postures of humans and the ability to express physical properties of fabrics, so clothing companies often produce real samples(Choi, 2021). Many raw materials are used in the sample production process, but the 3D virtual wear program can prevent unnecessary waste of resources by producing samples in a virtual space, and reduce the burden on the environment by reducing the amount of waste(Kim, 2020). In addition, patterns, textures, and designs can be produced and modified indefinitely without producing physical samples on a computer until just before final production, so

Table 2. *Kinds and Functional Characteristics of 3D Virtual Clothing Systems*

3D Virtual Clothing System (Company)	Manufacturing Country	Functional Characteristics
CLO 3D (CLO)	Korea2	· Intuitive Pattern Design · Real-time Interworking of Pattern Design and Virtual Attachment · Virtual Human Model Deformation · Clothing Simulation · 3D Fashion Show (real-time virtual fashion show)
Tuka 3D (Tukatech)	USA	· 3D Clothing Design · Virtual Human Model Deformation · Clothing simulation · 3D digital photography
Virtuality Fashion (C-DESIGN®)	France	· Pattern Design · 3D Clothing Design · 3D High Resolution Simulation · Virtual Showroom
V-Stitcher (Browzwear)	Israel	· Pattern Design · Virtual Human Model Deformation · Clothing Simulation · 3D Clothing Design
Optitex Creative (Optitex)	Israel	· 3D Clothing Design · Virtual Human Model Deformation · Clothing Simulation · Compatibility with 3D Computer Graphics Software
i-Designer (Tchnoa)	Japan	· Clothing Simulation · Virtual Coordination · Create Face Data · Make Fashion Accessories Data · Virtual Human Model Deformation
3D-Fit (Lectra)	France	· Pattern Design · Virtual Human Model Deformation · Clothing Simulation · 3D Clothing Design
DC Suite (TG3D Studio)	Hong Kong	· Pattern Design · Virtual Human Model Deformation · Clothing Simulation · 3D Clothing Design

clothes can be accurately implemented without going through many trials and errors that may occur in the business stage(Kim, 2020). In other words, the application of 3D digital technology in the clothing fashion industry has advantages as a practical alternative to the reduction of sample work process, reduction of sample production speed, low production cost, and aging of sample companies(Choi, 2021). Table 2 shows the types and functions of representative 3D virtual clothing software. CLO introduced the "Virtual ARMY" campaign in collaboration with Balmain and Shudu(the world's first digital supermodel). CLO's 3D designers created 3D clothing and bags using Balmain's real pattern for the 2018 Free Fall collection(Figure 15). The world's oldest French fashion school "ESMODE" has partnered with clothing CAD company Lectra to open a "meta-wear digital fashion course" to create a new vision for the future of fashion. As such, 3D virtual clothing software is being used in various fashion companies and universities. Recently, with the expansion of product modeling for virtual clothing and ergonomic design in Internet shopping malls, 3D virtual clothing systems can solve the problems of sample production, speed, and clothing purchase through e-commerce, and interest from companies and academia is increasing(Choi, 2021). Digital runways were released on YouTube channels such as fashion companies Time and KUHO and SNS such as Instagram, and LF introduced a three-dimensional virtual runway called Hedge Virtual Runway (HVR) in five countries(Figure 16). In addition, the online fashion platform W Concept introduced digital runways such as 'Frontlow', 'Recto', 'Maison Mare', and 'Instant Punk' as a way of communicating with customers in the fashion industry in the post-covid era, revealing major items of the season(Figure 17). Based on these technology competitiveness and characteristics, 3D virtual wear technology is a key technology in the future fashion industry, and it is believed that steady development and wide-ranging application plans are needed for 3D content of fashion products.

Ⅲ. Development of 3D Virtual Clothing Fashion Design Applying Frank Stella Painting

1. Design Planning and Textile Design Development

This study aims to develop a textile design that applies the formative characteristics of Frank Stella's painting and develop it as a 3D virtual clothing fashion. The production of the work was applied to the design using the formative lines, planes, structural forms, and colors characteristically revealed in Frank Stella's paintings as a new formative motif. The design development process was divided into design planning, design development, and work production, and the work was developed. First, in the design planning, the work to be a motif in Frank Stella's paintings was selected, and production techniques and color planning were established. Later, in

Figure 15. *CLO x Balmain x Shudu Collaboration*
(www.clo3d.com)

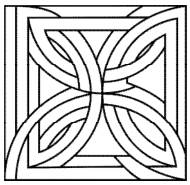
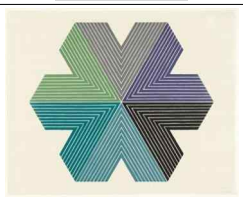
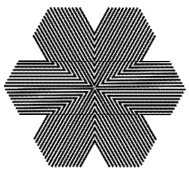
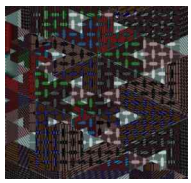
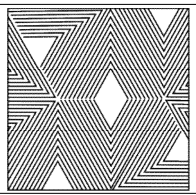
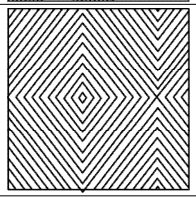
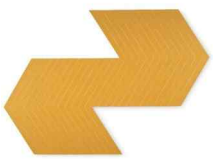
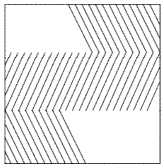
Figure 16. *Hazzys Virtual Runway*
(www.newspim.com)

Figure 17. *W.concept×Frontrow 2021 F/W Digital Runway*
(www.sisamagazine.co.kr)

the design development stage, costume patterns and textiles based on Frank Stella's painting work were developed, and in the process of producing the work, the silhouette and pattern were modified through simulation of 3D avatar outfits to supplement the textile design position. Patterns and textiles were developed using Photoshop programs, and virtual 3D fashion development was developed using CLO 3D programs to develop works.

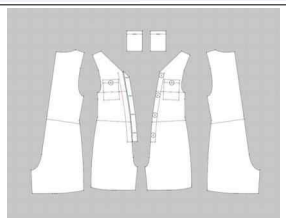
Among Frank Stella's works in the period of flat painting(1958-1970), the pattern design was developed with the motif of a total of six pieces, one in the Early,

Table 3. *The Textile Design Process Applying Frank Stella's Painting Works*

Design Idea / No	Motif Image	Motif Design	Textile Design Development
Textile Design 1			
Textile Design 2			
Textile Design 3			
Textile Design 4			
Textile Design 5			
Textile Design 6			

four in the middle, and one in the late. Subsequently, a total of six patterns were developed by reflecting the formability of 'unity due to regular stripes', 'asymmetry due to geometric surface division', and 'decorability due to colorful use' derived as a formative feature of Frank Stella's painting(Table 3). Textile Design 1 was transformed into a square and semicircle motif in Frank Stella's work in different sizes and placed with a straight line. Textile Design 2 created a single motif by separating the trapezoidal lines and surfaces, and arranged them irregularly. Textile Design 3 was designed so that the V-shaped straight line was repeated regularly and the texture was arranged in different sizes with the motif of forming a *shape, and geometric surface division was performed. Textile Design 4 extracted motifs by arranging V-shaped straight lines in various directions, and placed them in an image where thick straight lines intersect. Textile Design 5 uses these regular stripes in a straight line that repeats from the center toward the outside to construct a texture with geometrically divided images. Finally, Textile Design 6 developed a texture so that geometric images stand out using images that appeared as a motif of repeated straight lines. Textile Design 1 was variously modified in size with a square and semicircle motif in Frank Stella's work, and placed with a straight line. Textile Design 2 created a single motif by separating the trapezoidal lines and surfaces, and arranged them irregularly. Textile Design 3 designed the texture so that geometric surface division can be achieved by placing it in different sizes, with the motif of regular repetition of the *shaped V-shaped straight line. Textile Design 4 extracted motifs by arranging V-shaped straight lines in various directions, and placed them in an image where thick

Table 4. *Design Work 1*

Design 1		
Pattern	 	
Textile Design		Color 

(created by researchers)

straight lines intersect. Textile Design 5 uses these regular stripes in a straight line that repeats from the center toward the outside to construct a texture with geometrically divided images. Finally, Textile Design 6 developed a texture so that geometric images stand out using images that appeared as a motif of repeated straight lines.

2. Development of 3D Virtual Clothing Fashion Design

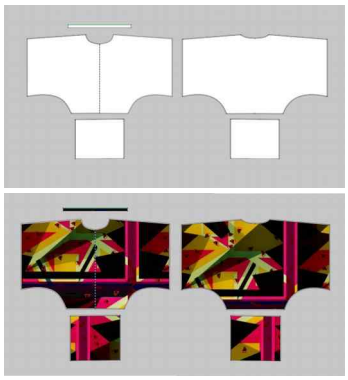
3D Virtual Clothing was designed by applying patterns developed by analyzing formative lines and symbolic images in Frank Stella's paintings. The theme of the work was designed with the concept of 'Easy Casual Wear', which is a comfortable and urban everyday wear, and 'Modern Feminine Wear', which is an elegant and sophisticated party wear, and applied the previously developed textile design to six virtual 3D fashion works.

Work I (Table 4) is a sleeveless jumpsuit designed to be worn comfortably in everyday life by excluding minimal silhouette and excessive decoration. The thick straight part of the developed textile was symmetrical to the shoulder end and the edge of the pants, giving the work a sense of unity. PB/dk, RP/vv, YR/wh, and BG/vv were used as the color, and R/dk was used as the point color.

Work 2(Table 5) is a mini dress with a kimono sleeve, designed using bk, Y/sf, RP/vv, GY/lt, and GY/dk colors. Sophistication was expressed by arranging geometric figures and color bands asymmetrically, and dynamics were created through contrast by giving points with RP colors to achromatic figures. By arranging patterns designed by freely arranging acute triangles of various colors, the work was produced so that a sense of rhythm could be felt, escaping from monotony.

Work 3(Table 6) is a set-up consisting of a

Table 5. *Design Work 2*

Design 2		
Pattern		
Textile Design		Color 

(created by researchers)

cardigan-type top and a maxi-length long pencil skirt. The patterns developed using BK, R/dk, G/dp, Y/dp, and B/◎ colors were placed together on the top and bottom to give a sense of unity. The pattern is characterized by an irregular arrangement of vertical, horizontal, and diagonal lines, giving a geometrically divided feeling. Pocket decoration was attached to the front of the top to give practicality, and it was developed as a work with a comfortable and modern sense.

Work 4(Table 7) is a square-neck A-line mini dress designed using R/dp, R/dk, Y/dp, Y/gy, and R/dp colors. The pattern repeated the geometric figure and expressed the outline with a thick line to eliminate monotony and show decorative properties due to complex patterns. In addition, an unbalanced design was expressed by giving points with R/dp on the front of the top and the back of the skirt.

Work 5(Table 8) is a long dress with a Queen Anne neckline. The dominant colors are bk and N3, and the colorful color bands such as BG/◎ and RP/◎ intersect in horizontal and diagonal lines to create an elegant image with a sense of movement. Mesh material is added to both sides of the skirt to add a dressiness, and the draped shoulder sleeves can be displayed in various ways, providing functional aspects and visual elements.

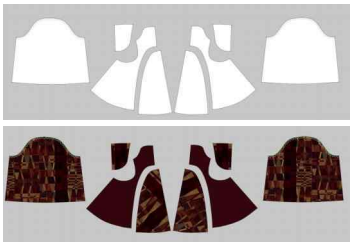
Work 6(Table 9) is a square neck midi dress with ruffle decorations added to the shoulder band to create dynamics through dynamic curves. The color emphasizes the decorative feeling by using various colors such as Y/dp, GY/dl, PB/dk, YR/sf, RP/dp, etc. Through the bold exposure of the back of the top, the outfit was highlighted, and the design with the drape of the shoulders and skirt part tried to bring out the feminine feeling.

Table 6. *Design Work 3*

Design 3		
Pattern		
Textile Design		Color 

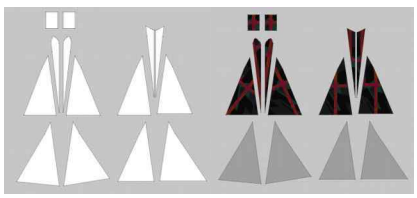
(created by researchers)

Table 7. *Design Work 4*

Design 4		
Pattern		
Textile Design		Color 

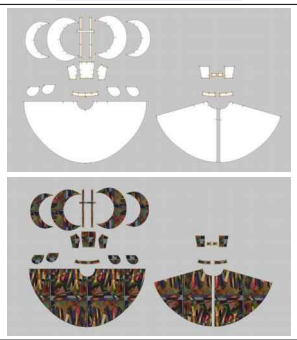
(created by researchers)

Table 8. *Design Work 5*

Design 5		
Pattern		
Textile Design		Color 

(created by researchers)

Table 9. *Design Work 6*

Design 6		
Pattern		
Textile Design		Color 

(created by researchers)

Ⅳ. Conclusion

This study examined the world of Frank Stella's work for the development of an original 3D virtual clothing fashion design based on the formative features of Frank Stella's paintings. As a result, the formative characteristics of Frank Stella's paintings were unity due to regular stripes, asymmetry due to geometric face division, and decorative characteristics due to the use of colorful colors. Based on these formative features, costume patterns and textiles based on Frank Stella's paintings were developed, and six 3D virtual fashion design works were developed by modifying and supplementing silhouettes and patterns through simulation of 3D avatar virtual clothes.

The conclusions obtained through the production of the work are as follows.

First, it was confirmed that Frank Stella's work has a very wide range of applicability to fashion products in various areas of work in which free expression of abstract expressionism and minimalistic simplicity coexist visually.

Second, the various colors and shapes in Frank Stella's paintings could be developed into textiles with visual formativeness, and originality as a fashion work that applied painting could be maximized.

Third, it was confirmed that the development of 3D fashion using a virtual program that combines painting and fashion has the ease of time efficiency, cost reduction, and spatio-temporal expansion of work processing compared to the actual process of producing clothes. In addition, through the simulation of 3D virtual clothing, the location of the pattern to be applied to the costume could be easily modified and recovered, and a

new design could be created in the process of changing the location of various textile.

In this thesis, I tried to present a new possibility of expression of fashion design based on artistic value by analyzing the formativeness of Frank Stella's paintings, which are challenging the possibilities and limitations through continuous change. Through this study, it is believed that it will be possible to help produce more aesthetic costumes by grasping the output direction of the texture developed before digital printing on the fabric or the location where the pattern will be cut. The limitation of the study is that it did not produce real works, so comparative analysis with 3D costume works was not conducted. Therefore, a follow-up study should be conducted to compare and analyze the location or direction of textiles in 3D clothing works by producing real works.

Painting and fashion are expected to reflect new values and actively interact with each other in a more diversified form as society changes. Accordingly, it can be said that the realm of virtual 3D fashion that combines painting with fashion has infinite possibilities. In addition, virtual 3D fashion, which can store and utilize the results indefinitely, can be used as a creative video at a digital fashion show that is expanding due to COVID-19. Therefore, it is hoped that this study, which developed 3D fashion, will be used as a basic data for the convergence content industry of painting and fashion in the future.

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