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A Study on Representation of 3D Virtual Fabric Simulation with Drape Image Analysis II

- Focus on the Comparison between Real Clothing and 3D Virtual Clothing -

Lee Minjeong · Sohn Heesoon* · Kim Jongjun**

Lecturer, Dept. of Clothing & Textiles, Sookmyung Women's University, Seoul, Korea
Prof., Dept. of Clothing & Textiles, Sookmyung Women's University, Seoul, Korea*
Prof., Dept. of Clothing and Textiles, Ewha Womans University, Seoul, Korea**

Abstract

This study aims to apply 3D virtual fabric parameters - as obtained from previous research experiments - to 3D virtual clothing simulation in comparing its similarity with actual clothing as worn, with a view to verifying the objectivity and validity of the 3D virtual fabric simulation method devised by the drape image analysis method. In addition, the result is intended to be used as the basic data for new 3D virtual clothing simulation methods. As the results, 3D virtual fabric parameters designed to simulate 3D drape to be similar to actual fabrics were found to be Bending Strength, Buckling Point, Density, Particle Distance, and Shear. They were also found to be important measurements when evaluating visual similarity between drape shadow images and number of nodes. 3D virtual fabric simulation method devised by the drape image analysis method was appropriate in extracting 3D fabric parameters with the reflection of actual fabrics' physical and dynamic characteristics, in connection with 3D virtual fabric simulation. 3D virtual fabric parameters with the reflection of actual fabrics' physical and dynamic characteristics using the proposed 3D virtual fabric simulation method are accumulated and provided as a standard, this will facilitate the introduction 3D virtual fabric simulation technology.

Key Words : 3D virtual fabric simulation, 3D virtual clothing simulation, drapability measurement, drape image analysis.

Corresponding author; Kim Jongjun, Tel.+82-2-3277-3102, Fax.+82-2-363-3078
E-mail: jjkim@ewha.ac.kr

Ⅰ. Introduction

3D virtual clothing simulation technology, which was radically developed for about 30 years, has been positively utilized in computer graphic industries such as animation, games, and filming. In recent years, IT and Web3D technology development is creating new business models as a new paradigm in the global fashion industry environment and digital fashion industry. In particular, the digital fashion industry is being highlighted and drastically being used in e-business as the foundations for 3D virtual clothing simulation technology and Web3D technology. In line with this trend, in recent years, research is being actively conducted regarding the possibility of 3D virtual clothing simulation's response to real clothing in various areas of computer engineering, textile engineering and clothing & textiles.

Speaking of domestic studies on 3D virtual clothing simulation, Oh[1], Kim[2], Son[3], Oh[4], Lee and Nam[5], Choi and Ko[6] reported on 2D clothing simulation and fabric modeling techniques using computer animation technology, thereby successfully implementing 3D virtual clothing simulation technology capable of producing clothing close to actual clothing. Lee[7], Lee[8], Wu[9], Lee[10], Ko[11], Kang and Kim[12], Koo and Suh[13], Kwon[14], Kim[15], Kang and Lee[16] conducted studies on the evaluation of wearing forms of real clothing and virtual clothing and of appearance thereof regarding clothing's silhouette, fitness, and expression of fabrics, in a bid to research on the possibility of 3D virtual clothing simulation's response to real clothing.

The 3D virtual clothing simulation technology requires reality-based fabric expression technology and technology for representation of actual clothes in connection with fitness. Of these, the 3D fabric expression, which is the key technology of expressing the virtual clothing silhouette, uses the computer graphic technology 3D animation technology. These technologies offer physical numbers unlike actual dynamic and physical fabric properties, making it difficult to define actual connection between them, and having visual image limitations. Thus, a study is needed regarding a more quantitative and objective fact evaluation method.

Thus, in previous research,[17] drapability, which influences clothing's exteriors and silhouette among various fabric characteristics, was measured by shooting actual drape images of fabrics using a DrapeMeter, and visual similarity between actual fabrics and simulated 3D virtual fabrics was evaluated, thus evaluating the characteristic parameters of 3D virtual fabrics. This study aims to apply 3D virtual fabric parameters - as obtained from previous research experiments - to 3D virtual clothing simulation in comparing its similarity with actual clothing as worn, with a view to verifying the objectivity and validity of the 3D virtual fabric simulation method devised by the drape image analysis method. In addition, the result is intended to be used as the basic data for new 3D virtual clothing simulation methods.

Ⅱ. Method

1. Experiment Devices and Conditions

In this study, fabric samples <Table 1>, as well as drape image analysis methods and 3D virtual fabric characteristic parameters by fabric sample were made to be the same as with previous research.[18] The 3D virtual clothing simulation program used in the experiments was CLO 3D v.3.09 developed by the local company

CLO Virtual Fashion Ltd.., and in analyzing drape images, the New Drape Measurement Sytem, DrapeMeter[19], developed by the Korean company D&M Technology Ltd., was used. Computer hardware specification constituted Intel Core i7 CPU 820QM, Memory 4GB, NVIDIA GeForce GT 335M 1024MB. Fabric images were photographed with a Sony CyberShot DSC-T70 Digital Camera, and they were made to be similar to the actual fabric as much as possible regarding the fabric textile image and scale and color, using Adobe Photoshop CS2.

2. Drapability Measurement

Herein used was the same method as in the previous study[20], DrapeMeter(D&M Technology Ltd.) was measured by the textile product drapability test method (KS K 0115:2002)[21] under the Korean industry standards.

The DrapeMeter can get 2D images of draped shadows with the installation of supplementary devices (camera, support, frame, etc.) onto a widely used Cusick Drape Tester-type measurement device. 2D image analysis can get drape coefficients and the information of other various drape forms, thus analyzing textile drapability quantitatively. There are three defined form factors, namely, no. of nodes, wave amplitude(mm), and wavelength(degree). To enable the simulation of drape models based on these form factors, the drape modeller was designed.[22] <Figure 1>[23] shows DrapeMeter measurement method, process and analysis of results (DrapeMeter measures drapability of fabrics on the basis of drape formation factors obtained through the image input device).

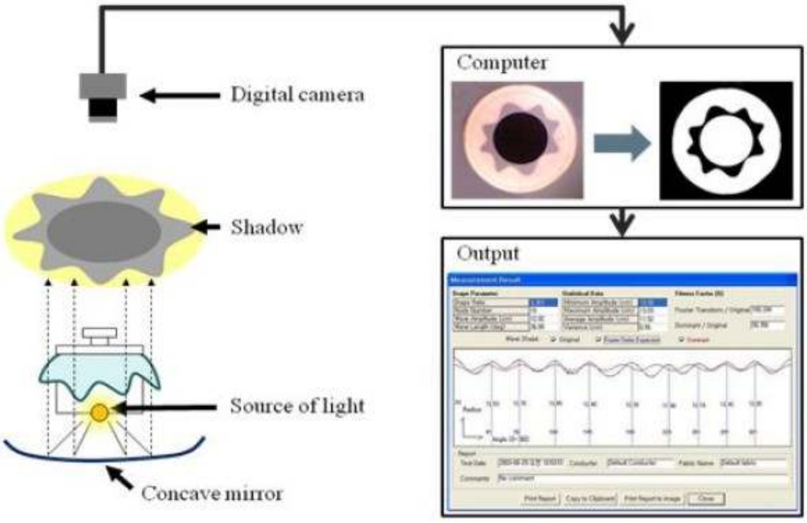
Experiment method involves collecting samples of textile - which resemble a circle with a diameter of 30cm - and conducting experiments. Basically, one sample by fabric was collected and measured in a total of six times (front and rear sides were measured three times each), and then average was evaluated and used.

3. Simulation of 3D Virtual Fabrics

Herein used was the evaluation method based on visual similarity, as provided by Lee and Nam(as cited in Lee et al., 2011). Visual similarity is a method to visually observe similarity between a computer-simulated virtual textile and an actual textile, and as such, after virtual textile and actual textile become similar, the final value is taken by controling parameters, thus evaluating textile materials. This method enables obtaining of characteristics of fabrics without using machines.[24] Fabric parameters designed for assessing visual similarity were set as in <Table 2> after reflecting parameters - as used in KES(Kawabata Evalutation System) - such as

<Table 1> Fabric Parameters

Sample No.	Type of Fiber	Class of Fabric	Weave	Fabric Count (threads/inch)		Fabric Thickness (mm)	Weight (g/㎡)	Drapability(%)
				Warp	Weft			
1	Silk	Woven	Satin	280	144	0.17	69	21.9
2	Wool	Woven	Twill	80	64	0.35	160	44.3
3	Wool	Woven	Herringbone	29	21	1.57	328	52.0
4	Cotton	Woven	Plain	80	80	0.20	81	64.1



<Figure 1> New Drape evaluation system using an image processing method –*Study on Drapability of Fabrics and Generation Tools for 3D Digital Garments", Unpublished master's degree thesis,* p.6.

Stretch, Shear, Bending, Thickness, Weight, Damping, Reflection, and Transparency. Fabric parameters are parameters designed for control physical features of fabrics with CLO 3D V.3.09.

With regard to the parameters established in <Table 2>, and were manufactured into 3D circle patterns with a diameter of 30cm as samples used in measurement with the DrapeMeter.

<Table 2> 3D Virtual Fabric Drape Parameters

CLO 3D Properties
Stretching(Weft) Strength
Stretching(Warp) Strength
Shearing Strength
Bending Strength
Buckling Point(Length Ratio)
Particle Distance
Internal Damping
Density
Shininess
Transparency

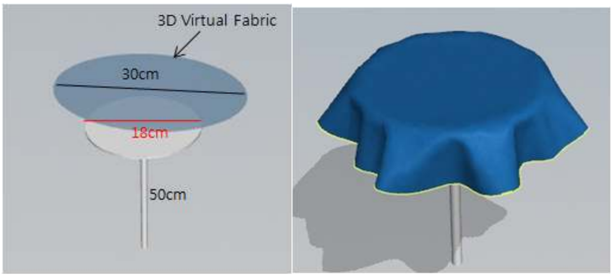
Fabric texture images as photographed with digital camera were mapped onto circle patterns, and the 3D virtual fabric simulation environment was configured into a circle table with a diameter of 18cm as with the DrapeMeter <Figure 2>. Then, the experiment extracted 3D virtual fabric parameters as the actual fabric drape shape images that correspond to parameters established in <Table 2>.

4. Simulation of 3D Virtual Garments

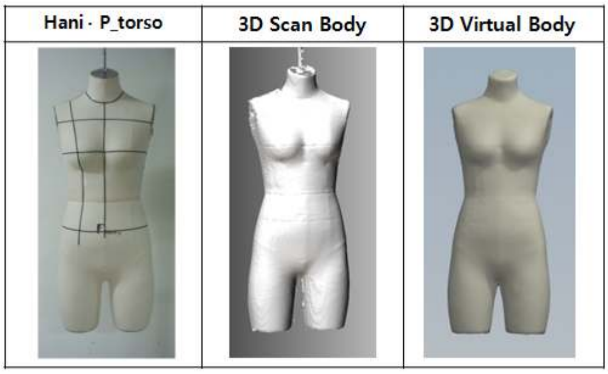
1) Test Body

The body to wear clothing – used in the experiments – was the FitnBody(FitenBody Ltd.)[25] it for the standard Korean women in their 20s, and the body canned with a WB4(Cyberware Ltd.) 3D scanner, and the scanned image was simulated into 3D virtual clothing <Figure 3>.

Hani · p_torso size specifications involve a waist girth of 65cm (66cm was adopted herein), and a hip girth of 90.5cm.



<Figure 2> CLO 3D virtual fabric simulation test method *-This researcher picture*



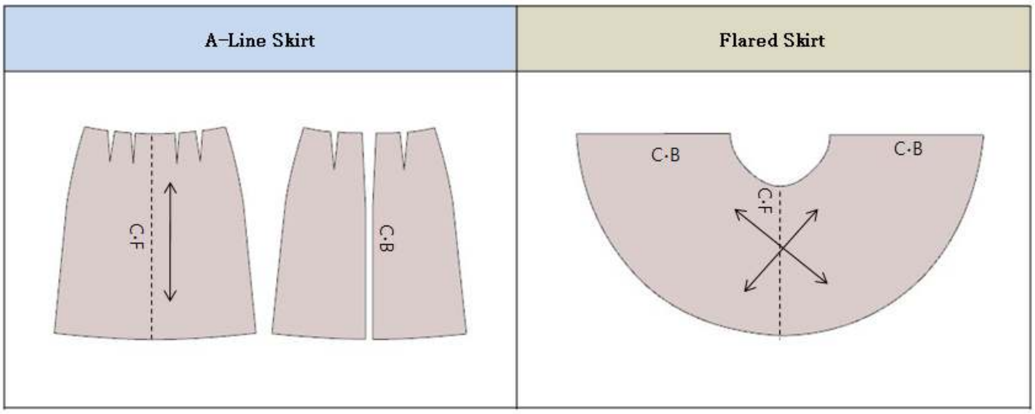
<Figure 3> The body to wear clothing*-This researcher picture*

2) Types of Test Clothing and Manufacturing of Patterns

Women's basic wear item A-line Skirt, and 180° flared skirts with which drapability can be best observed, were used as test clothing types. One set of test clothing by fabric sample was manufactured in a total of eight sets.

A-line skirt consisted of three gore of center front fold line, and the skirt length was set as 60cm. Virtual wearing patterns were manufactured according to ESMOD manufacturing method using the CLO 3D program <Figure 4>. Waist line margin to seam was set as 1.5cm, allowing it to be folded inside the skirt, and belts were not separately manufactured. According to research by Jocheon (早川) et. al. reporting that the skirt hem line influences material characteristics, skirt hem length, and other factors, the margin to seam around the skirt was not folded, and fabrics were cut without a margin to seam[26)], and the skirt front center's straight grain line was set as vertically.

Flared skirts consisted of one sheet of back side finishing, and the skirt length was set as 60cm. Virtual wearing patterns were manufactured according to the circular arc method using the CLO 3D program <Figure 4>. Waistline margin to seam and skirt hem were designed the same as with A-line skirt. The flared skirt front center's on bias, on the basis of research by Kim(as cited in Kim, Yoo, Jin, and Hong et al., 1993) reporting that forward bias produces



<Figure 4> Types of Test Skirts and Patternmaking

-This researcher picture

excellent drape beauty effects.[27)]

Test clothes herein were manufactured with a Singer 191E-20 sewing machine, DB 11 size needles, and 9 needle stitches/inch.

3) 3D Virtual Fitting Simulation Procedure and Condition

3D virtual clothing simulation form tests of test clothes were performed according to CLO 3D V.3.09 Manual. The procedure order was retrieval of import 3D virtual body(.obj) > manufacturing of skirt patterns > virtual sewing of skirts > deployment of patterns > retrieval of skirt textures > setting of 3D virtual fabric parameters > execution of simulation > saving the result.

3D virtual clothing simulation form experiment conditions involved measuring drapability of skirts by differentiating cutting angles according to skirt type changes. The cutting angle of A-line skirts with small drapability was set as grain line direction (0 degree), and the cutting angle of flared skirts with superior drapability was set as bias direction (45 degrees) <Figure 4>. Afterwards, 3D virtual fabric parameters by sample, as extracted with the same method as with previous research, were used in identifying appropriate conditions designed to express skirt drape simulation to be similar to actual clothing.

4) Analysis Method for Comparative Evaluation of Wearing Shape of real Clothing and Simulated Clothing

For sensory evaluation herein, photos of wearing real clothing and virtual clothing were classified according to fabric sample types and skirt types, and a total evaluation table was created so as to allow examiners to evaluate photos at a glance. Two sensory evaluations were conducted. In the first sensory evaluation, 3D virtual parameters by fabric sample, as extracted, were applied in examining appropriate conditions designed to express skirt drape simulation to be similar to real clothing. In the second sensory evaluation, 3D virtual fabric parameters were adjusted to fit appropriate conditions produced in the first sensory evaluation, and skirt simulation was improved, and was reevaluated. Evaluation items included one item of silhouette and color each, five items about materials in a total of seven question items. Evaluation method used was the five-point scale (Linkert-Test Scale), and scores, which approached 5 points, were assessed as positive results. Regarding evaluation results, each question score was added up and was averaged, and each average score was added up, thus evaluating total average. Other opinions were used in examining analysis results.

Evaluators included two graduate school students or graduates majoring in clothing and textiles, two fashion designers with over ten years of experience, and two 3D virtual clothing simulation designers in a total of six people.

III. Results

1. Simulation of 3D Virtual Fabrics

Drape factors, as measured through the DrapeMeter of textile samples, were analyzed quantitatively as in <Table 3>. Drape Ratio is percentage of drape factor, and as it decreases, the drapability of cloth increases and the number of nodes (number of drape pleats) increases. Sample 1 silk had a drape ratio of 0.219 and node number of 8, offering the best drapability. Sample 4 cotton had a drape ratio of 0.641 and a node number of 6, offering the lowest drapability. Also, as drape's major curve size, namely, wave amplitude (measured from the center of a sample), decreases, the drapability improves. Wave length has a close relation with node number. Also, as in <Figure 5>, as a result of analysis of drape parameters and drape shadow form images, as the drapability improves, the number of nodes increases, and starlike pointed shadow form images appear; as wave amplitude and wave length increase, drapability worsens. Of four wool items of sample 2, items with node number of 9 were formed in the largest number, but their drapability value was smaller than that of silk items of sample 1. This suggests that although the node number is great, different values can be produced according to physical fabric properties such as fabric unit weight and bending strength. Thus, drape components such as drape ratio, node number, wave amplitude and wave length have a close correlation, and drapes are differently formed according to properties of fabrics. Based on measured drape factor results, as the drape ratio decreased, and as node number increased, the drapability improved: Drapability superiority order was Sample 1 silk > Sample 2 Wool > Sample 3 Wool > Sample 4 Cotton.

After the number of drape shadow shape images as measured by the DrapeMeter and the node number were set as the same, the 3D virtual fabric parameters extracted from visual similarity evaluation are shown in <Table 4>. Major factors, which influence fabric drapability, were found to be Bending Strength, Buckling Point, Density, Particle Distance and Shear. Also, these proved to be an important measure of evaluating the visual similarity between the number of drape shadow shape images and node number. These test results are very consistent with opinions of Cusik(as cited in An et al., 1982)[28] saying that bending length, shear, etc. are closely related to drapability expressing cloth's external beauty, as well as with the result of dynamic properties relationship tests - as obtained through KES - regarding drape factors using the drape image analysis method of Gwon[29] saying that bending, tension, shear, and weight per unit area have important effect on fabric drapability. Also, test results based on visual similarity assessment, and parameter bending used in KES showed a correlation with 3D virtual fabric parameters such as Bending Strength, Buckling Point(Length Ratio), Density, and Particle Distance, and also parameter weight used in KES showed a correlation with Density and Particle Distance. In addition, parameter shear used in KES showed a correlation with 3D virtual fabric parameter Shearing Strength, and there was a high correlation regarding fabric cutting angle, namely, grain line direction and bias direction. To expressfabrics more realistically, fabric surface's shininess and transparency were found to be very important parameters. Numbers in brackets in <Table 4> are non-dimensional constants used in 3D virtual clothing simulation programs and represent their respective textile properties.

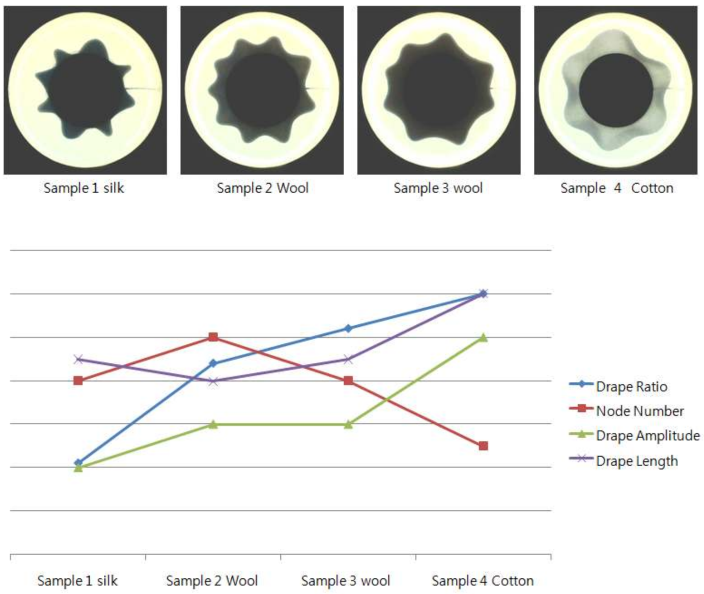
2. Simulation of 3D Virtual Garments

1) The First Simulation of 3D Virtual Garments

3D virtual fabric parameters, as extracted from

<Table 3> drape parameters

Sample 1 Silk		Sample 2 Wool		Sample 3 Wool		Sample 4 Cotton	
Drape Ratio	0.219	Drape Ratio	0.443	Drape Ratio	0.520	Drape Ratio	0.641
Node Number	8	Node Number	9	Node Number	8	Node Number	6
Wave Amplitude (cm)	11.43	Wave Amplitude (cm)	12.65	Wave Amplitude (cm)	12.67	Wave Amplitude (cm)	13.90
Wave Length(deg)	45.00	Wave Length(deg)	40.00	Wave Length(deg)	45.00	Wave Length(deg)	60.00



<Figure 5> Relationship between drape parameters and drape shadow shapes *-This researcher picture*

<Table 4> Comparisons between KES and 3D virtual fabric drape parameters, CLO 3D Properties of the fabric according to the four kinds of assessment data (Original)

KES Properties	Fabric / CLO 3D Properties(scale)	Sample 1 Silk	Sample 2 Wool	Sample 3 Wool	Sample 4 Cotton
Stretch	Stretching(Weft) Strength (0-99)	15	38	38	38
	Stretching(Warp) Strength (0-99)	15	37	37	37
Shear	Shearing Strength (0-99)	65	17	17	17
Bending	Bending Strength (0-99)	20	31	43	35
	Buckling Point(Length Ratio) (0-99)	46	80	80	72
Weight	Density (0-99)	26	35	35	21
	Particle Distance (5-20)	5-10	10	10	5
Damping	Internal Damping (0-99)	4	1	1	1
Reflection	Shininess (0-128)	18	114	128	68
Transparence	Transparency (0-100)	100	90	100	82

each fabric sample, underwent 3D virtual simulation using CLO 3D v.3.09, and a total evaluation table of <Table 6> was created, thus evaluating similarity between real clothing and virtual clothing based on evaluation of the appearance of wearing skirts. For sensory evaluation results in <Table 5>, in the case of A-line Skirt, a total average of 3.10 "Normal" was produced, and in the case of flared skirts, a total average of 2.73 "A little not so" was produced. Appropriate conditions for expressing skirt drape simulation to be similar to real clothing are slightly different between two types of skirts, but fabric transparency, fabric pattern and texture, and fabric surface shininess were negatively evaluated in this order. In addition, evaluation of a big deviation of A-line Skirt and Flared Skirt concerned questions about fabric drapability (including pleat shapes), and appropriate conditions were found to be different according to cutting direction.

2) The Second Simulation of 3D Virtual Garments

<Table 7> shows 3D virtual fabric parameters as appropriate conditions designed to express skirt drape simulation to be similar to real clothing.

<Table 5> First Sensory Evaluation of Patterns of Wearing Real Clothing and Virtual Clothing (n=6)

Item	Question	A-line Skirt	Flared Skirt
Silhouette	Are overall silhouettes of real clothing and virtual clothing similar?	3.4	3.5
Color	Is fabric color of real clothing and virtual clothing similar?	3.4	3.7
Fabric	Is the fabric surface shininess of real clothing and virtual clothing similar?	2.7	3.0
	Are fabric patterns and textures of real clothing and virtual clothing similar?	2.4	2.6
	Is fabric transparency of real clothing and virtual clothing similar?	2.3	2.3
	Is fabric drapability of real clothing and virtual clothing similar(including pleat shapes)?	4.0	3.0
	Is the expression of overall fabric texture sense of real clothing and virtual clothing similar?	3.5	3.3
Average		3.10	2.73

For specific appropriate conditions, in order to improve negatively evaluated factors in the first 3D virtual clothing simulation such as skirt fabric transparency, fabric pattern and texture, and fabric surface shininess, shininess value was adjusted by adding specular parameter as in <Table 7>. Also, to make fabric patterns and texture identical, photos of fabric images were amended with Photoshop, and then were simulated. Second, shear and particle distance, which influence cutting direction, were adjusted to be suitable for fabric sample characteristics, and were applied to flared skirts. Likewise, the shear of sample 4 cotton, which produced the worst drapabililty as a result of tests, was lowered, and particle distance was lowered overall.

The second sensory evaluation table with the reflection of improved 3D parameters is shown in <Table 9>, and evaluation results revealed that as shown in <Table 8>, total average was 3.53 and 3.23 for two types, respectively, improving. In addition, duplicate evaluation opinions were proposed as follows: in the case of fabric patterns like Sample 3 Wool, texture and pattern images are not realistic; in the case of fabrics like Sample 4 Cotton, which are sparse, bright in color, and transparent, facticity is the worst, virtual clothing's fabric weight looks light; in the case of flared skirts of all fabrics, pleats look exaggerated, and the skirt is so closely contacted with the body, lowering facticity; in the case of Sample 1 Silk, flexibility is good, and in the case of skirts with a thin texture, the side-line cutting line is unnatural.

IV. Conclusion

In order to verify the objectivity and validity of the 3D virtual fabric simulation method devised by the drape image analysis method, tests of clothing wearing shapes were conducted to compare and evaluate similarity between real clothing and 3D virtual clothing simulation. The results are outlined as follows.

<Table 6> The First Total Evaluation of Photos of Wearing Real Clothing and Virtual Clothing

Skirt types / Fabrics	A-Line Skirt		Flared Skirt	
	Real	Virtual	Real	Virtual
Sample 1. Silk				
Sample 2. Wool				
Sample 3. Wool				
Sample 4. Cotton				

3D virtual fabric parameters designed to simulate 3D drape to be similar to actual fabrics were found to be Bending Strength, Buckling Point, Density, Particle Distance, and Shear. They were also found to be important measurements when evaluating visual similarity between drape shadow images and number of nodes.

Also, visual similarity evaluation tests revealed that Bending, which has the greatest effect on fabric drapability, had relevancy to 3D virtual fabric parameters of Bending Strength, Buckling Point(Length Ratio), Density, and Particle Distance, and that fabric Weight had relevancy to 3D virtual fabric parameters of Density and

<Table 7> Comparisons between KES and 3D virtual fabric drape parameters, CLO 3D Properties of the fabric according to the four kinds of assessment data (Second)

KES Properties	CLO 3D Properties(scale) \ Fabric	Sample 1 Silk	Sample 2 Wool	Sample 3 Wool	Sample 4 Cotton
Stretch	Stretching(Weft) Strength (0-99)	15	38	38	38
	Stretching(Warp) Strength (0-99)	15	37	37	37
Shear	Shearing Strength (0-99)	65	17	17	9
Bending	Bending Strength (0-99)	20	31	43	35
	Buckling Point(Length Ratio) (0-99)	46	80	80	72
Weight	Density (0-99)	26	35	35	21
	Particle Distance (3-5)	5	5	5	3
Damping	Internal Damping (0-99)	4	1	1	1
Reflection	Specular (0-255)	111, 111, 111	47, 47, 47	47, 47, 47	0, 0, 0
	Shininess (0-128)	1	4	4	0
Transparence	Transparency (0-100)	100	100	100	99

<Table 8> The Second Sensory Evaluation of Patterns of Wearing Real Clothing and Virtual Clothing (n=6)

Item	Question	A-line Skirt	Flared Skirt
Silhouette	Are overall silhouettes of real clothing and virtual clothing similar?	3.5	3.5
Color	Is fabric color of real clothing and virtual clothing similar?	4.2	4.0
Fabric	Is the fabric surface shininess of real clothing and virtual clothing similar?	3.3	3.3
	Are fabric patterns and textures of real clothing and virtual clothing similar?	3.0	2.7
	Is fabric transparency of real clothing and virtual clothing similar?	2.7	2.3
	Is fabric drapability of real clothing and virtual clothing similar(including pleat shapes)?	4.3	3.3
	Is the expression of overall fabric texture sense of real clothing and virtual clothing similar?	3.7	3.5
Average		3.53	3.23

<Table 9> The Second Total Evaluation of Photos of Wearing Real Clothing and Virtual Clothing

Skirt types / Fabrics	A-Line Skirt		Flared Skirt	
	Real	Virtual	Real	Virtual
Sample 1. Silk				
Sample 2. Wool				
Sample 3. Wool				
Sample 4. Cotton				

Particle Distance. The fabric shear, when simulating 3D virtual clothing, had relevancy to 3D virtual fabric parameter, Shearing Strength, as well as high relevancy to fabric cutting angle associated with clothing types, namely, grain line direction and bias direction.

Putting first and second sensory evaluation results and other opinions, the 3D virtual fabric simulation method devised by the drape image analysis method was appropriate in extracting 3D fabric parameters with the reflection of actual fabrics' physical and dynamic characteristics, in connection with 3D virtual fabric simulation. However, in order to enhance similarity in fabric pattern, texture and transparency in expressing tactility, fabric image shooting methods should be linked to other computer graphic programs that can realistically express fabric images, and this should be explored as a method designed to improve 3D virtual clothing simulation.

To date, with 3D virtual clothing simulation, methods of expressing fabrics realistically have been used implicitly. Such methods require high professional computer graphics skills. Unskilled people have been required of long-time efforts. This led to totally different results depending on levels of individuals' simulation skills. As a standardized method to solve these problems, if the database of the 3D virtual fabric parameters, reflecting the actual fabrics' physical and dynamic characteristics, are to be utilized based on the method of 3D virtual fabric simulation, suggested by this study, the technological introduction of the 3D virtual clothing simulation system into the apparel industries would be much facilitated.

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