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Comparison of Virtual Avatars by Using Automatic and Manual Method

Ho-Sun Lim[†] · Cynthia L. Istook*

Research Institute of Clothing & Textile Sciences, Yonsei University

*Dept. of Textile Technology & Management, North Carolina State University

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Abstract

New technology that includes 3D body scanning, digital virtual human, and digital virtual garments has had a significant impact on the current apparel industry. Virtual simulation technology enables the visualization of a 3D virtual garment on a virtual avatar so that consumers can try on garments with their virtual avatars before purchasing. However, the manual virtual avatar provided for online apparel shopping currently has revealed limitations on the different body sizes and shapes of customers. This study analyzes the process of designing the automatic virtual avatar and the manual virtual avatar using OptiTex software; in addition, the study compares the practicality of the automatic virtual avatar with that of the manual virtual avatar. Data was examined by evaluating how much each virtual avatar is similar to the real body and how well it matched the needs of the current apparel industry. In the study, Avatar 1 was automatically created from three-dimensional body scan data and Avatar 2 was manually created from body measurements. The virtual avatar images laid over a real body image and the results were evaluated by comparing the simulated sizes of virtual avatars with those of a real body. Consequently, Avatar 1 was evaluated as more similar to the real body than Avatar 2 in all five body shapes. This study illustrates that an automatic virtual avatar might solve the fit problem that is the most common reason for a high return rate for online shopping. The results show that future virtual simulation technology needs to be improved for the practicality of the virtual avatars.

Key words: 3D body scanning, Virtual avatar, Digital human, Virtual simulation, Online shopping

I. Introduction

Apparel companies currently focus more on providing mass customization, since consumers desire to personalize the clothing style, fitness, color and material. Consumers using on-line shopping have increased dramatically and on-line shopping for apparel has increased especially. However, consumers are still hesitant to purchase garments online and high return rates continue, because they rely on two-dimensional photos of garments and sizing charts and cannot try on clothing before purchase (Horrigan, 2008; Volino et al., 2005). Therefore, a new technology of digital virtual human and garment has been developed for the apparel industry. The virtual simulation technology is currently available to online apparel retailers by My Virtual Model (www.mvm.com). In this website, consumers are able to select the body sizes of virtual avatar and try the selected garments on the virtual avatar (Istook, 2008; Loker et al., 2008). However, there are still the limitations of body sizes and shapes of the virtual avatar. For example, there are just three choices including hourglass, triangle, and inverted triangle for body shape, just two choices including small-medium and medium-large for the bust size, and two choices including undefined and well-defined for the waist size. This limited selection is imperative that a virtual avatar with the exact size and shape of the consumer is used for the accurate fit of a garment (Istook, 2008).

Many researchers have worked on the development

[†]Corresponding author
E-mail: maresea@gmail.com

of virtual try-on CAD systems based on a three-dimensional avatar (human body model), garment, and fabric drape simulation (Cordier et al., 2001; Divivier et al., 2004; Hardaker & Fozzard, 1998; Kartsounis et al., 2003; Kenkare, 2005; Volino et al., 2005; Yu & Xu, 2008; Yunchu & Weiyuan, 2007). The virtual avatar (digital human model) is used to many industries as well as apparel industries and many researchers have studied the digital human model, human motion, virtual simulation for the car seat (Mavrikios et al., 2006; Siefert, 2008; Yang et al., 2009) and the digital human model for ergonomic design in virtual environment (Jung et al., 2009). However, there have been limited evaluations of the practicality of automatic and manual virtual avatars for the accurate the fit of garments despite the increase of virtual technology studies as an academic discipline.

The purpose of this research was to compare the practicality of the automatic virtual avatar made by the automatic transfer from body scan data with the manual virtual avatar made by the manual input from body measurements in the evaluation of a virtual avatar that is similar to a real body.

II. Methods

1. Participants

Seventy-nine participants at North Carolina State University (NCSU) took part in a three-dimensional body scan in January and April of 2009. They are students, employees, and visitors at North Carolina State University's College of Textiles wishing to participate in the subjects for this study.

2. Procedure

The design of the experiment was two virtual avatars (automatic and manual) and five body shapes (Hourglass, Bottom Hourglass, Rectangle, Oval, and Spoon). In this study, a $[TC]^2$ body scanner was used to measure the body shape of the participants. The measurements of all participants were processed over an appropriate fitted body suit or over underwear and the body data were saved in .RBD, .ORD, .VRML, and .BIN file formats. Body shapes of all participants were categorized into nine body shapes including Hourglass, Bottom Hourglass, Oval, Rectangle, Spoon, Top Hourglass, Triangle, Inverted Triangle, and Diamond by Visual Basic Pro software called FFIT (Female Figure Identification Technique) for Apparel (Simmons et al., 2004). This software contains computer codes programmed to classify body shape by analyzing anthropometric data such as the circumferences of bust, waist, hip, stomach and abdomen as criteria for body type classification. Each of the subjects' measurement data was analyzed using this code of FFIT software and their body shapes were determined by this process. We selected 5 representative subjects through random sampling from those with one of the five body shapes 'Hourglass,' 'Bottom Hourglass,' 'Rectangle,' 'Oval' or 'Spoon' as defined by Simmons et al. (2004).

The subjects' body data and measurements were used to create the automatic and manual virtual avatars by using OptiTex software system. The automatic virtual avatar (Avatar 1) was created through the automatic input of body scan data while the manual virtual avatar (Avatar 2) was processed through a manual input of the body measurements. In addition, the real bodies used in this experiment were the actual body shapes of five subjects measured in the $[TC]^2$ body scanning system and saved in VRML format. This study evaluated the practicality of the automatic virtual avatar (Avatar 1) and the manual virtual avatar (Avatar 2) in a comparison of two avatar images with real body images. A real body image was laid on the top of Avatar 1 image and Avatar 2. The differences of the sizes between virtual avatars and a real body in five body dimensions (breast width, bust, waist, abdomen, and hip) were compared in a front view and side view. The size difference (D1) of Avatar 1 indicated the difference between the real body measurements and Avatar 1 measurements and size difference (D2) of Avatar 2 indicated the difference between the real body measurements and the Avatar 2 measurements. They were reported in units of inches.

1) Avatar 1

The body data of participants were saved and were used to create an automatic virtual avatar (Avatar 1).

However, the raw data required reconstruction before further processing to build a virtual avatar, because the raw point cloud data (*.RBD) from the body scanner generally includes significant missing data (e.g. the hair, the legs, and the armpits). Therefore, they were transferred to OBJ morph avatar data (*.OBJ) which is a polygonal mesh model using an avatar morphing operation of a NX-16 software system as shown <Fig. 1>. The morph model data (OBJ file) of the final subjects were automatically imported into the OptiTex software system as shown in <Fig. 2>.

2) Avatar 2

The body measurements of the participants extracted the Measurement Extraction Profile (.MEP file) of $[TC]^2$ and were used to create a manual virtual avatar. The body measurement system of the MEP file was formed by the same body measurement system of an existing virtual avatar (OptiTex software). <Table 1> shows body measures that are obtainable in the $[TC]^2$ body scanning system and are included in the model properties window through which the body measurements of OptiTex software are entered for creating a manual virtual avatar. In order to measure these body size items, the corresponding items were programmed in the Measurement Extraction Profile (.MEP file) of $[TC]^2$.

The body measurements of the participants extracted

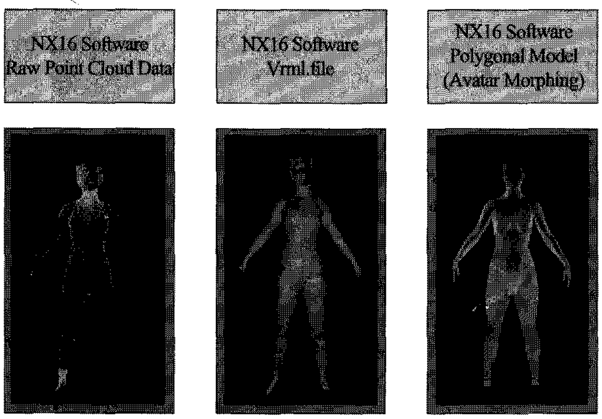


Fig. 1. Avatar morphing operation of NX-16.

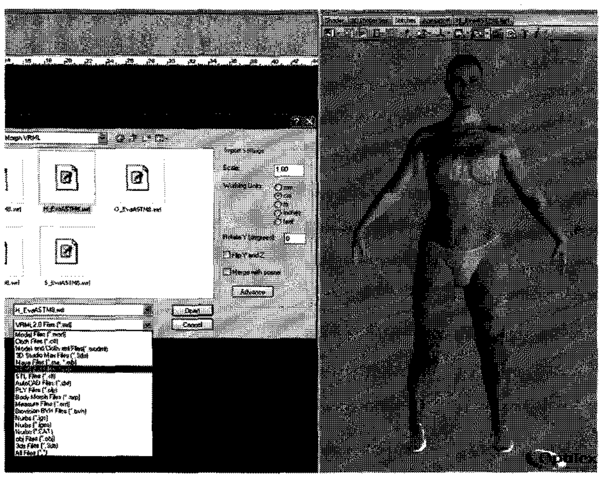
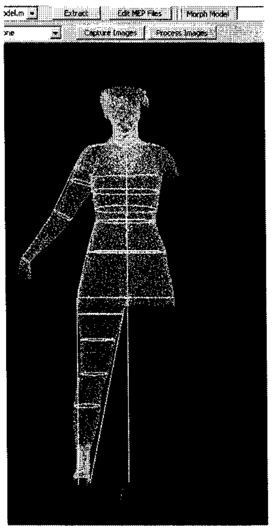


Fig. 2. 3D direct virtual avatar imported from morph model file.

by the MEP file of the $[TC]^2$ body scanner as shown in <Fig. 3> were manually typed into each measurement column of the existing virtual avatar in the OptiTex software as shown in <Fig. 4>.

Table 1. Measurements between OptiTex and $[TC]^2$

Category	Measurements
Basic	Height, Size
Height	CervicalHeight, BustHGT, UndBustHGT, OutSeam, Inseam, HipHeight, HighHipHeight, KneeHGT
Length	ArmscyeDEPTH, BPtoBP, Waist2Hips, Shoulders, ArmsLength
Girth	MidNeck, BaseNeck, UnderBust, Breast, Waist, Hips, HighHip, Thigh, MidThigh, KneeWidth, Calves, Ankle, Biceps, Elbow, Wrist ShoulderSlope



ORDERID=OptiTex_Modulate_and_Model
OPTION UNITS=cm
MEASURE Height=171.9
MEASURE Size=75.9
MEASURE CervicalHeight=148.9
MEASURE ShoulderSlope=3.8
MEASURE BustHGT=124.4
MEASURE UndBustHGT=117.9
MEASURE Outseam=112.9
MEASURE Inseam=76.9
MEASURE HipsHeight=79.4
MEASURE HighHipHeight=98.8
MEASURE KneeHGT=46.4
MEASURE ArmscyeDEPTH=16.4
MEASURE BPtoBP=18.2
MEASURE Waist2Hips=34.0
MEASURE Shoulders=36.1
MEASURE ArmsLength=56.6
MEASURE MidNeck=34.0
MEASURE BaseNeck=36.1
MEASURE UnderBust=75.9
MEASURE Breast=88.4
MEASURE Waist=72.3
MEASURE Hips=107.3
MEASURE HighHip=90.8
MEASURE Thigh=60.8
MEASURE MidThigh=50.5
MEASURE KneeWidth=38.9
MEASURE Calves=37.3
MEASURE Ankle=34.6
MEASURE Biceps=31.6
MEASURE Elbow=23.7
MEASURE Wrist=14.9

Fig. 3. MEP file and ORD file of $[TC]^2$ body scanner.

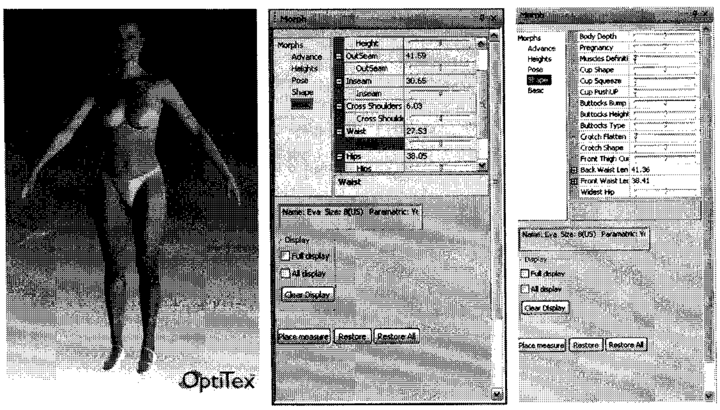


Fig. 4. 3D manual virtual avatar input from body measurements.

III. Results

<Table 2> shows the means, minimums, maximums and standard deviations of anthropometric measurements used in the body type classification of 79 subjects using the FFIT (Female Figure Identification Technique) software for apparel. The FFIT software took the body scan data of 79 subjects and categorized subjects into nine basic body shapes including 'Hourglass (16.5%)', 'Bottom Hourglass (25.3%)', 'Oval (7.6%)', 'Rectangle (30.4%)', 'Spoon (12.6%)', 'Top Hourglass (1.3%)', 'Triangle (6.3%)', 'Inverted Triangle (0%)', and 'Diamond (0%)'. According to the results of this study, the body shapes of Hourglass, Bottom Hourglass, Oval, Rectangle and Spoon, which were defined as the top five body shapes in Simmons et al. (2004), were frequent, and thus our results were consistent with their study of Simmons et al. (2004).

In addition, <Table 3> shows anthropometric measurements of the 5 representative subjects, who were classified, respectively, into the top five body shapes. We made an automatic virtual avatar (Avatar 1) and a manual virtual avatar (Avatar 2) using the measurements of each body type and compared them with the real body.

The results of the size difference between virtual avatars and a real body are provided in <Fig. 5>, <Fig. 9>. A real body image was laid on of the top of an automatic avatar (Avatar 1) and was laid on the top of a manual avatar (Avatar 2) in the evaluation of the practicality of the automatic and manual virtual avatars. The red shade indicates a real body, a black shade indicates the automatic avatar, and the blue shade indicates a manual avatar. The size difference between the real body and the two virtual avatars was measured at the front angle and a side angle.

1. Bottom Hourglass

<Fig. 5(a)> shows the overlapped images between a real body and the virtual avatars with a Bottom Hourglass body shape, in addition it is possible to view them from the front and side angles. <Fig. 5(a)> indicates the size differences with BH. <Fig. 5(a)> shows that the automatic avatar (Avatar 1) was not significantly different from the real body in a comparison of the automatic avatar torso with the real body torso. In contrast to the automatic avatar (Avatar 1), the manual avatar (Avatar 2) was significantly different from the real body, in a comparison of an automatic avatar torso with a real body torso.

In <Fig. 5(a)>–<Fig. 5(b)>, Avatar 2 was smaller than that of the real body. <Fig. 5(c)>–<Fig. 5(d)> illustrates how the sizes between the virtual avatars and a real body are different. The front view measured the size differences between the virtual avatar and a real body at the waist, abdomen, and hip lines, because the size differences at the breast width and bust lines were unclear in the measurement.

The front view of <Fig. 5(c)> shows that the size difference values (D1) between Avatar 1 and a real body are zero in the waist, abdomen, and hip. The size difference values between Avatar 2 and a real body are negative. This shows that Avatar 2 is smaller than the real body. The significant difference values (D2) between Avatar 2 and a real body are as follow: waist (right), D2=-1.0 inch, waist (left), D2=-1.0 inch, abdomen (right), D2=-0.8 inch, abdomen (left),

Table 2. Descriptive analyses of 79 participants' body measurements (Unit: cm)

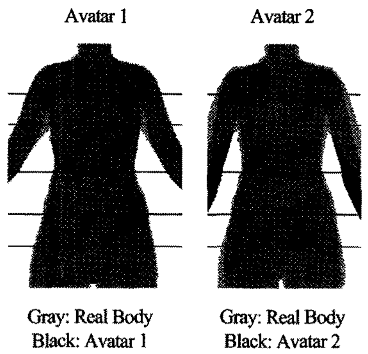
	Mean	Min	Max	S.D.
Bust	37.3	30.7	48.9	3.6
Waist	30.5	23.0	42.8	4.0
Hips	40.4	34.9	49.9	3.2
Stomach	32.6	26.6	45.2	3.8
Abdomen	34.8	27.0	49.8	4.6
HighHip	34.5	28.0	46.1	3.9
UnderBust	31.5	23.4	43.9	3.7

Table 3. Body measurements of five final subjects (Top five body shapes) (Unit: cm)

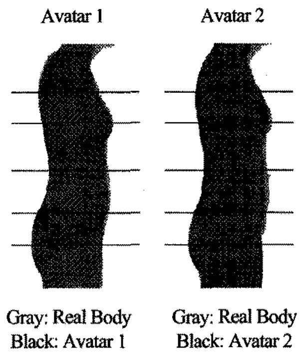
	Hourglass	Bottom Hourglass	Oval	Rectangle	Spoon
Height	162.8	171.9	172.8	165.1	164.9
Size	74.6	75.9	104.5	88.0	83.4
CervicalHeight	139.8	148.9	149.8	142.1	141.9
ShoulderSlope	5.9	3.8	5.3	4.8	4.7
BustHGT	118.0	124.4	122.3	120.6	119.1
UndBustHGT	111.5	117.9	117.8	114.1	111.1
Outseam	103.3	112.9	110.4	99.5	104.4
Inseam	70.7	76.9	76.9	72.9	75.9
HipsHeight	73.0	79.4	92.8	75.0	79.1
HighHipHeight	90.6	98.8	102.9	89.4	93.6
KneeHGT	42.0	46.4	46.3	45.0	44.6
ArmscyeDEPTH	17.0	16.4	17.2	18.0	15.9
BPtoBP	17.9	18.2	23.7	21.4	19.0
Waist2Hips	31.9	34.0	18.7	25.5	25.9
Shoulders	32.4	36.1	43.3	39.4	37.1
ArmsLength	49.9	56.6	57.9	51.3	54.7
MidNeck	33.9	34.0	41.8	32.0	34.3
BaseNeck	36.9	36.1	44.1	34.2	35.3
UnderBust	74.6	75.9	104.5	88.0	83.4
Bust	89.0	88.4	124.2	102.8	99.3
Waist	66.4	72.3	106.9	82.3	79.0
Hips	97.7	107.3	126.9	101.9	106.4
HighHip	84.5	90.8	111.3	91.5	96.5
Thigh	54.6	60.8	73.3	57.2	60.8
MidThigh	44.8	50.5	61.9	47.6	48.7
KneeWidth	34.8	38.9	44.0	36.1	36.3
Calves	34.5	37.3	42.6	35.3	36.3
Ankle	22.4	34.6	26.4	24.7	22.0
Biceps	28.5	31.6	38.2	31.8	30.8
Elbow	23.3	23.7	30.4	23.1	23.4
Wrist	14.3	14.9	17.1	15.4	14.5

D2=-0.5 inch, hip (right), D2=-0.5 inch, hip (left), D2=-0.5 inch.

Regarding the side view in <Fig. 5(b)>, the center backline (from a neck point to a hip point) of the real body was a deeper curve than that of the manual avatar. The center frontline (from a bust level to the hip level) of the real body was more protruded than that of the manual avatar. As shown in <Fig. 5(d)>, the sizes of Avatar 1 and a real body are similar at the bust, waist, abdomen, and hip. In contrast to Avatar 1, the sizes between Avatar 2 and a real body are different. The significant difference values (D2) between Avatar 2 and a real body are as follow: bust (back), D2=+0.4 inch, bust (front), D2=-1.0 inch, waist (back), D2=+0.5 inch, waist (front), D2=-1.0 inch, abdomen (back), D2=+0.5 inch, abdomen (front), D2=-0.8 inch, hip (back), D2=+0.3 inch, hip (front), D2=0.0 inch. The results show that the automatic avatar was almost the same as the real body while the manual avatar was different.



(a) Overlapped images in front view



(b) Overlapped images in side view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Waist	0	0	-0.2	-0.1
Abdomen	0	0	-0.2	-0.1
Hip	0	0	-0.2	-0.1

(c) Size differences in front view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Breast Width	0	0	0	0
Bust	0	0	0.4	-1.0
Waist	0	0	0.5	-1.0
Abdomen	0	0	0.5	-0.8
Hip	0	0	0.3	0

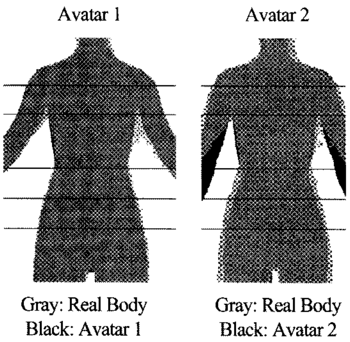
(d) Size differences in side view

Fig. 5. Difference between body and virtual avatars of Bottom Hourglass.

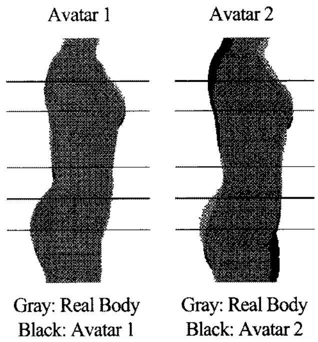
2. Hourglass

<Fig. 6> displays the overlapped images and the size differences of a body and virtual avatars with an Hourglass body shape. As shown in <Fig. 6(a)> (front view)–<Fig. 6(b)> (side view), Avatar 1 was similar to the real body, but Avatar 2 was significantly different from the real body. In the front view, <Fig. 6(a)> shows that Avatar 2 was smaller than the real body. Regarding the side view in <Fig. 6(b)>, the hip shape of the real body was up, while that of Avatar 2 was down. In addition, the back shape of the real body was crooked when compared to that of Avatar 2.

<Fig. 6(c)>–<Fig. 6(d)> illustrate the size differences between virtual avatars and a real body. In <Fig. 6(c)> (front view), the size difference values between Avatar 1 and a real body are zero in the waist, abdomen, and hip. However, the size difference values (D2) between Avatar 2 and a real body are different. The significant difference values between Avatar 2 and a real body are as follow: waist (right), D2=-1.0 inch, waist (left), D2=-0.8 inch, abdomen (right), D2=-1.0 inch, abdomen (left), D2=-0.5 inch, hip (right), D2=-0.5 inch, hip (left), and D2=-0.1 inch. In Avatar 1 of <Fig. 6(d)> (side view), the waist size value showed a small difference in value: waist (back), D2=+0.05 inch, waist (front), and D2=-0.05 inch. The size difference values between Avatar 2 and a real body are as follow: breast width (back), D2=+0.9 inch, breast width (front), D2=-1.2 inch, bust (back), D2=+0.2 inch, bust (front), D2=0.0 inch, waist (back), D2=-0.1 inch, waist (front), D2=-0.1 inch, abdomen (back), D2=-1.5 inch, abdomen (front), D2=0.0 inch, hip (back), D2=-1.0 inch, and hip (front), D2=+0.1 inch.



(a) Overlapped images in front view



(b) Overlapped images in side view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Waist	0	0	-1.0	-0.8
Abdomen	0	0	-1.0	-0.5
Hip	0	0	-0.5	-0.1

(c) Size differences in front view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Breast Width	0	0	0.9	-1.2
Bust	0	0	0.2	0
Waist	0.05	-0.05	-0.1	-0.1
Abdomen	0	0	-1.5	0
Hip	0	0	-1.0	0.1

(d) Size differences in side view

Fig. 6. Difference between body and virtual avatars of Hourglass.

3. Oval

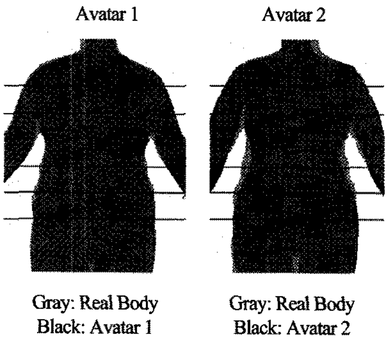
<Fig. 7> presents the Oval body shape. <Fig. 7(a)> (front view)-<Fig. 7(b)> (side view) identifies that Avatar 2 was different from the real body. In <Fig. 7(a)> (front view), Avatar 2 was smaller than the real body at the waist line. For the side view in <Fig. 7(b)>, the bust cup shape of the real body was up, while that of Avatar 2 was down. The abdomen of the Avatar 2 was flatter than that of the real body. <Fig. 7(c)> (front view) shows that the size difference values (D2) between Avatar 2 and a real body are as follow: waist (right), D2=-1.0 inch, waist (left), D2= -0.8 inch, abdomen (right), D2=-0.8 inch, abdomen (left), D2=-0.1 inch, hip (right), D2=+0.1 inch, hip (left), and D2=+0.4 inch.

<Fig. 7(d)> (side view) shows the size difference values between Avatar 2 and a real body as follows: breast width (front), D2=-1.0 inch, bust (front), D2= +0.2 inch, waist (back), D2=+0.8 inch, waist (front), D2=-1.0 inch, abdomen (back), D2=+0.3 inch, abdomen (front), D2=-1.1 inch, hip (front), and D2=-2.0 inch. The results show that Avatar 2 was significantly different from the real body.

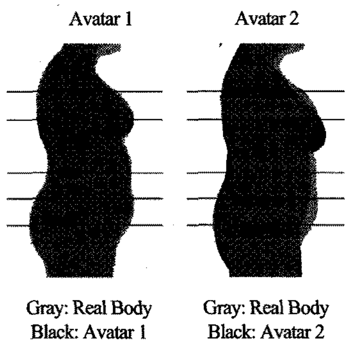
4. Rectangle

<Fig. 8> displays the Rectangle body shape. <Fig. 8(c)> (front view) shows the size difference values (D2) between Avatar 2 and a real body as follow: waist (right), D2=-0.7 inch, waist (left), D2=-0.7 inch, abdomen (right), D2=-0.7 inch, abdomen (left), D2= -0.7 inch, hip (right), D2=0.0 inch, hip (left), and D2= -0.5 inch.

<Fig. 8(d)> (side view) shows the size difference values (D2) between Avatar 2 and a real body as follow: breast width (back), D2=+0.9 inch, breast width (front), D2=+0.3 inch, bust (back), D2=0.0



(a) Overlapped images in front view



(b) Overlapped images in side view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Waist	0	0	-1.0	-0.8
Abdomen	-0.1	0	-0.8	-0.1
Hip	0	0	0.1	0.4

(c) Size differences in front view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Breast Width	0	-0.1	0	-0.1
Bust	0	0	0	0.2
Waist	0	0	0.8	-1.0
Abdomen	0	-0.1	0.3	-1.1
Hip	0	-0.1	0	-2.0

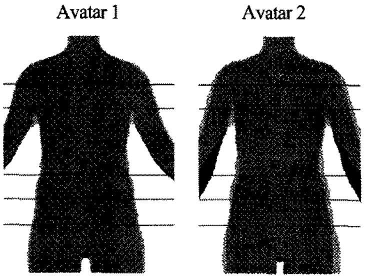
(d) Size differences in side view

Fig. 7. Difference between body and virtual avatars of Oval.

inch, bust (front), D2=+1.2 inch, waist (back), D2=+0.1 inch, waist (front), D2=+0.8 inch, abdomen (back), D2=0.0 inch, abdomen (front), D2=+0.1 inch, hip (back), D2=+0.6 inch, hip (front), and D2=0.0 inch. The result shows Avatar 2 was significantly different from the real body. <Fig. 8(b)> (side view)–<Fig. 8(d)> (side view) show the front parts of Avatar 2 (breast width, bust, waist, abdomen, and hip) were larger and more protruded than a real body. The result indicate that Avatar 1 was almost the same as the real body, but Avatar 2 was significantly different from the real body.

5. Spoon

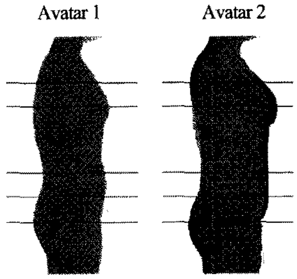
<Fig. 9> presents Spoon body shape. For the side view in <Fig. 9(b)> (side view)–<Fig. 9(d)> (side view), the back shape of a real body was crooked when compared to that of Avatar 2. The examination of the size difference values (D2) between Avatar 2 and a real body in <Fig. 9(d)> (side view) suggests: breast width (back), D2=+1.8 inch, breast width (front), D2=-1.8 inch, bust (back), D2=+1.2 inch, bust (front), D2=-0.8 inch, waist (back), D2=+0.9 inch, waist (front), D2=0.0 inch, abdomen (back), D2=0.0 inch, abdomen (front), D2=+0.1 inch, hip (back), D2=+0.1 inch, hip (front), and D2=+0.1 inch. For the front view in <Fig. 9(a)> (front view)–<Fig. 9(c)> (front view), Avatar 2 was smaller than the real body. In <Fig. 9(a)>, the real body had a protrude shape (i.e. 'shelf' shape) at the high hips (abdomen), but the manual avatar did not have a shelf shape. The shelf shape is essential to create a virtual avatar of a Spoon body shape, because the Spoon body shape is characterized with a shelf at the high hips as based on the research by Simmons et al. (2004). The results identified that Avatar 2 was different from the real body.



Gray: Real Body
Black: Avatar 1

Gray: Real Body
Black: Avatar 2

(a) Overlapped images in front view



Gray: Real Body
Black: Avatar 1

Gray: Real Body
Black: Avatar 2

(b) Overlapped images in side view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Waist	0	0	-0.7	-0.7
Abdomen	0	0	-0.7	-0.7
Hip	0	0	0	-0.5

(c) Size differences in front view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Breast Width	0	0	0.9	0.3
Bust	0	0	0	1.2
Waist	0	0	0.1	0.8
Abdomen	0	0	0	0.1
Hip	0	0	0.6	0

(d) Size differences in side view

Fig. 8. Difference between body and virtual avatars of Rectangle.

IV. Conclusions

This study evaluated the appearance of the automatic virtual avatar and the manual virtual avatar to identify which one is similar to a real body.

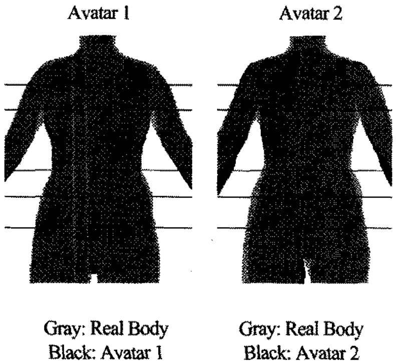
The findings from this study are as follows.

First, Avatar 1 was automatically made by importing from morph model data (OBJ file) while Avatar 2 was manually made by inputting the body measurements from the measurement extraction profile (.MEP file). In the manual method for Avatar 2, there weren't the system to set the accurate position of body measurements entered in existing virtual avatars of virtual software when entering body size items into the MEP file of the $[TC]^2$ body scanning system. Therefore, there was a limitation in the compatibility of the same body measurements between virtual software and the body scanning system. Also, there remains the problem that the body shapes and poses might vary with each operator in the creation of a manual virtual avatar.

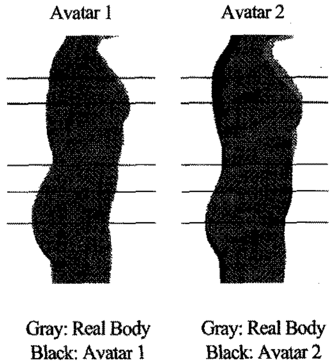
Second, Avatar 1 was almost same as the real body while Avatar 2 was different from the real body in the case of all five body shapes that included Hourglass, Bottom Hourglass, Oval, Rectangle, and Spoon. In the manual method that creates virtual avatars by entering body measurements, because body size items entered into virtual software are mainly heights, lengths and girths, it was considered necessary to have items for entering thicknesses and angles for reflecting thicknesses and shapes of an actual human body.

Third, Avatar 2 (manual avatar) of Oval shapes was significantly different from a real body. In that, the abdomen of the Avatar 2 was flat while that of the real body was protruded.

Fourth, compared to Avatar 2, Avatar 1 reflected the measurements and shapes of an actual body, but it had the limitation that it cannot make a variety of



(a) Overlapped images in front view



(b) Overlapped images in side view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Waist	0	0	-0.1	-0.5
Abdomen	-0.1	-0.1	-0.8	-0.8
Hip	0	0	-0.4	-0.4

(c) Size differences in front view

(Unit: inch)

	Avatar 1		Avatar 2	
	Right	Left	Right	Left
Breast Width	0	0	1.8	-1.8
Bust	0	0	1.2	-0.8
Waist	0	0	0.9	0
Abdomen	0	0	0	0.1
Hip	0	0	0.1	0.1

(d) Size differences in side view

Fig. 9. Difference between body and virtual avatars of Spoon.

body poses. Therefore, it was considered necessary to improve further in the technological aspect. For Avatar 2, it was meaningful in that a virtual avatar reflecting actual body sizes could be created just through entering body measurements, but for creating a virtual avatar reflecting actual body sizes more accurately, further improvement was required.

Virtual avatars and garments using these digital technologies are expected to be utilized actively in the clothing and fashion industry. In this sense, the use of the automatic virtual avatar that is similar to the real body is a possible solution to the problem of the difference in the body size and shape of the virtual avatar and the real body. This is a promising method for reducing the return rate caused by the fit problem in apparel online shopping. However, it is considered necessary to improve the virtual try-on technology for the automatic virtual avatar and the manual virtual avatar.

Future research should investigate the convergence of virtual technologies and digital convergence in the IT and fashion industries in the examination of practical uses for the fashion marketing.

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