Check for updates

IJCF
pISSN 2233-9051
eISSN 2288-7490
https://doi.org/10.7233/ijcf.2021.21.1.014
International Journal of Costume and Fashion Vol. 21 No. 1, June 2021, pp. 14-24

A Study on the 3D Body Scan Data Editing Process and Errors Analysis for Clothing Design

Kyoung Sun Kim · Younglim Choi†

Assistant Professor, Dept. of Fashion Design, Sangji University, Wonju, South Korea

Associate Professor Dept. of Fashion Design/Art & Design Institute, Daegu University, Daegu, South Korea

Abstract This study aims to enhance the usage of 3D body scan\ data by proposing a 3D body scan data editing process for clothing design and analyzing factors causing errors by editing processes. The 3D body scan data were collected by using the Body Line Scanner of Hamamatsu, and the configuration of scan data was analyzed by using the RapidForm 2006 program. For the 3D body scan, unmeasured parts necessarily occur, because of the principle of measurement. In addition, some errors are also caused by rotation angles, in developing symmetry for clothing design. Moreover, other errors can occur, in arranging surfaces and editing mesh, for enhancing the quality of 3D body figures. In order to minimize the factors causing such errors, this study suggests a novel 3D body scan editing process consisting of following steps: rotation of scan data, editing of unmeasured parts, arrangement of scan data surfaces, mesh editing of scan data and the horizontal flip of scan data. The findings of this study as basic research for standardizing 3D body scan data and enhancing the quality of scan data are expected to help increase the usage of 3D body scan data.

Keywords Clothing design, 3D body scan data, Editing process, Quality of scan data, Error

Citation Kim, K. S., & Choi, Y. (2021). A study on the 3D body scan data editing process and errors analysis for clothing design. *International Journal of Costume and Fashion*, *21*(1), 14-24.

Introduction

The 4th industrial revolution, characterized by the convergence of technologies, is bringing about significant changes in the apparel industry. Recently, rapid development of information, communication and microprocessor technology has also brought many changes across the industry. In particular, the development of digital technology has also led to innovations in the textile and fashion industries, enabling product planning, production, and consumption using three-dimensional technology and virtual space or virtual reality applications. According to this innovation, the textile and fashion industry is changing from a manufacturer-centered industry to a consumer-centered industry (Park & Kim, 2004). In line with this changing environment of the apparel industry, the method of measuring the human body, which is the basis of clothing design, should be redefined.

Anthropometric measurement refers to the task of quantitatively identifying the size or morphological characteristics of the human body using a certain instrument (Shim, 1996). Data obtained through anthropometric measurements provide the basis for the ergonomic design of personal equipments including clothing, footwear, furniture, and everyday goods as well as for standard somatotype and body type classification. Existing anthropometric measurements have mainly relied on a measuring tape and Martin anthropometer while new measurement techniques using a three-dimensional human body scanner have been studied to shorten the measurement time and effort. The 3D

Received May 24, 2021; **Revised** June 5, 2021; **Accepted** June 9, 2021

† ***Corresponding Author:*** orangebk@daegu.ac.kr

human body scanner refers to a non-contact type 3D scanner for human body measurement that can obtain 3D shape information of the human body in a short time. The 3D measurement method, which started as a measurement using shadows in the early 1970s, began to develop rapidly in the 1990s thanks to advances in electronic technology and computers, and various devices and software have been developed. In reality, 3D human body data has a tremendous potential not only in its own value but also in its application. In addition, 3D anthropometric measurement can extract and analyze various 3D shape information such as surface area, volume, and shape of each part from the collected data so that it is very useful in the field of product design and analysis.

With the rapid expansion of e-commerce, interest in the three-dimensional approach for individual body type analysis and anthropometric measurement is growing in the apparel industry. In the era of the 4th industrial revolution, the focus of the apparel industry would move from mass production into individual customization. It is expected that this type of production could create a sustainable market by balancing supply and demand. Along with changes in the market environment of the apparel industry and the segmented preferences of consumers, the method of apparel production is changing from mass production to diversified small-quantity production, mass customization, and individual customization. Due to the nature of apparel products designed and manufactured to fit the human body in consideration of fashion trends, the change in production method is encouraging in that it can reduce the burden of inventory and reduce production costs. However, supporting technology must be accompanied.

Recently, studies on 3D human body scan data for clothing design have been published such as automatic measurement to acquire human body dimensions from 3D scan data, a flat deployment that transforms 3D shape information into 2D patterns, and representative body shape modeling. These research topics are actively being studied to utilize 3D human body scan data in clothing design as well as a basic study for the production of individual customization. Research using 3D human body scan data should involve a process of editing 3D human body scan raw data, but previous studies to standardize the editing process are very limited. Without standardization of the editing process, different editing processes and error tolerance across each study may bring negative effects on data compatibility and the comparison of research findings, resulting in obstacle for the utilization of 3D human body scan data and the development of research.

In this work, we aim to propose a standard editing process for standardizing the 3D human body scan data editing process for clothing design and analyze the error factors across the editing process in order to increase the utilization of 3D human body scan data. The research topics of this paper are as follows. First, we investigate the need for the editing process by analyzing the 3D human body scan raw data. Second, we propose an editing process to enhance the usage of the 3D human body scan data. Third, we identify the factors that can cause errors across the editing process of the 3D human body scan raw data.

Background

Anthropometric measurement method for clothing design

Accurate measurement of the physical dimensions of the human body are fundamental to a wider range of design industries based on ergonomic design principles (Yoon et al., 2004). There are two primary methods of body measurement consisting of direct and indirect measurement method. The direct measurement method is a technique of measuring the human body using the Martin anthropometer to identify the length, perimeter, height, width, and thickness of the human body. The indirect measurement method includes the contour line method, the sliding gauge method, and the 3D measurement method, which has been greatly developed in recent years.

Direct measurement of the human body for clothing design. The most traditional method of anthropometric measurement for clothing design is to measure the dimensions of the human body by directly contacting the Martin anthropometer as shown in Figure 1. The Martin anthropometer is an internationally standardized

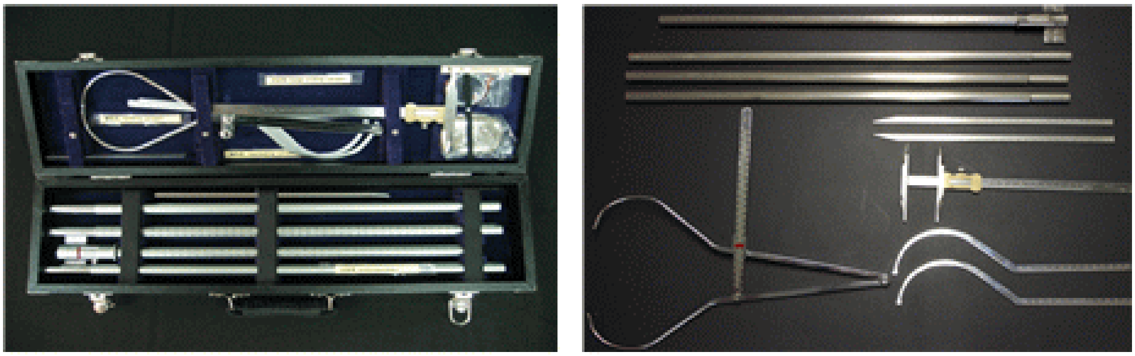

Figure 1. Direct human body measurement system of the Martin anthropometer

anthropometric instrument. The size standards of the International Organization for Standardization (ISO) and Korean industrial standards (KS) are also based on the data measured by the Martin anthropometer (Lee et al., 2002). The direct human body measurement method using the Martin anthropometer has the advantage of high reliability and easy data compatibility as the measurement method has been established for a long time. On the other hand, the disadvantage is that it requires a lot of time and effort for both the measurer and the subject. In addition, the accuracy of the result may vary depending on the proficiency of the measurer. The measurement errors also may result from the inability of the subject to maintain the same posture, the inexperience of the measurer, typo and omissions by the recorder.

3D human body scan for clothing design. The 3D body scanner is a device designed for human body measurement that allows for the acquisition of 3D digital data on the appearance The 3D body scanner is a device designed for human body measurement that allows for the acquisition of 3D digital data on the appearance of a human body existing as a three-dimensional body in space, rather than a two-dimensional plane image of an object (Ju, 2003).

Three-dimensional human measurement has the advantage of saving measurement time and effort and acquiring shape information of the human body. However, there are disadvantages in that relating equipment and system is somewhat expensive. In addition, database compatibility is difficult because measurement methods and measurement landmarks have not been standardized so far.

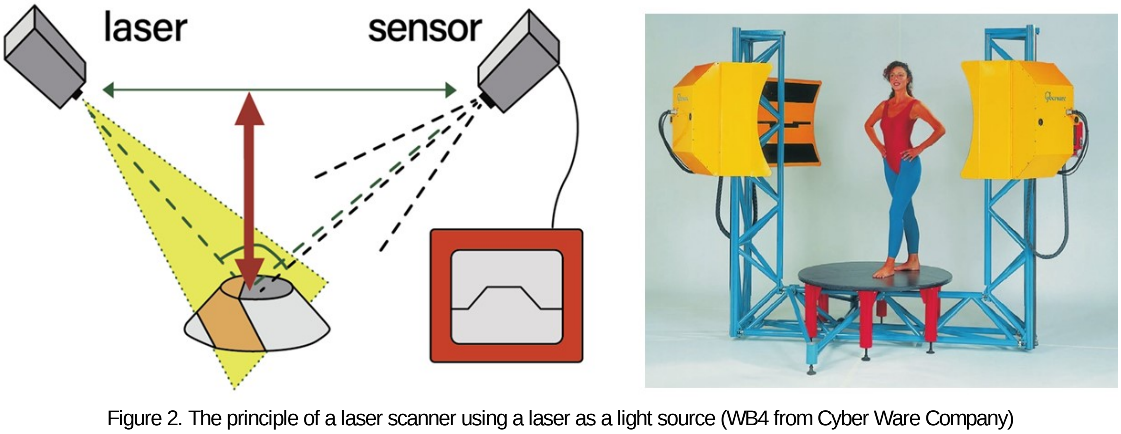

Figure 2. The principle of a laser scanner using a laser as a light source (WB4 from Cyber Ware Company)

The 3D human body scanner can be divided into a method using a laser light source, a method using a white light source, and a method using a microwave depending on the measurement technique. The laser scanner using a laser as a light source is the first commercialized method among non-contact measurement technologies. As illustrated in Figure 2, it is a method of reconstructing a three-dimensional surface expression by obtaining three-dimensional coordinates by optical triangulation using the laser projection distance and projection angle and analyzing them (D'Apuzzo, 2007).

In the case of measuring a small object without movement, one camera can be rotated while measuring. However, in the case of the human body, 2~4 cameras are utilized simultaneously since it is difficult to not remain stationary for a long time. In addition, it is common to move laser light sources and cameras along the vertical direction of the human body, due to the narrow range of measurements that can be made at the same time (Kim, 2008). A major drawback of Laser scanners is the high price of the hardware in that scanner components consist of lasers, optical sensors, optical systems, and precision electric motors. In addition, the simultaneous use of multiple cameras makes it difficult for calibration to be done perfectly well. It also takes a long time to digitize a large surface. Moreover, measurement errors may occur due to breathing or small movements of the human subject. There might be an unmeasured area such as the top of the head, axilla, and crotch since the camera moves in the vertical direction of the human body.

As illustrated in Figure 3, the method of using a white light source is to obtain surface coordinates by installing a grid in front of the light source and capturing the shadow of the grid projected onto the object with a camera (Ju, 2003).

Since the white light projection method is measured in units of planes, the system can be configured by properly arranging several cameras with no need to move the camera like a laser scanner. The main difference from laser scanners is that the scanning and digitization speed is very fast. In addition, it has the advantage of being free from errors caused by breathing or movement since it can be measured in a short period of time. In order to scan a large area such as a human body using a white light projection method, a complex scanning device is required. In addition, since the surface coordinates are obtained using the shadow of the grid projected on the object, an unmeasured area is generated in the area where the shadow occurs due to the curvature of the human body.

The most recently developed method is to collect body surface silhouette data through clothing materials using the principle of detecting human body moisture, allowing measurement of body surface shape data while wearing clothing (Park, 2012). Scanners using high-frequency microwaves are utilized to measure only the necessary dimensions from data in the form of a probability distribution rather than an exact surface shape. Therefore, their precision is relatively low compared to other scanners.

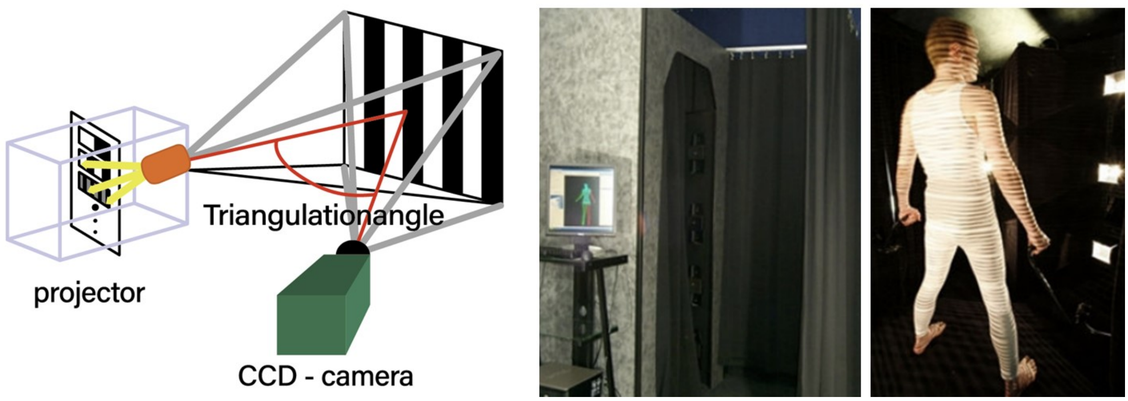

Figure 3. The principle of white light projection type scanner using a white light as a light source (TC2 from TC2 Company)

Utilization of 3D anthropometric data for clothing design

Automatic measurement of 3D human body shape dimensions. A typical application of 3D human body scan is a large-scale anthropometric measurement project. In order to set standards in various industries, 3D anthropometric measurement is evaluated as a suitable method due to the short measurement time and reproducibility since statistical analysis based on large-scale measurements is required.

In the 6th SizeKorea project conducted in 2010, a large-scale anthropometric measurement was made with a laser scanner. A number of studies have been conducted to automatically acquire human body dimensions using the 3D human body scan data from the large-scale anthropometric measurements as follows. Han (2007) studied the automatic setting of 3D body landmarks and measuring paths for apparel. Kim et al. (2016) investigated the automatic measurement of 3D body angle for apparel. Kim (2018) developed a script based universal 3D body measurement system.

Pattern development using 3D human body surface. In order to design clothes suitable for the body type, it is necessary to develop patterns that reflect not only the size information of the human body but also the shape information of the human body. Various studies have been conducted to automatically design patterns using human body shape information. Kim (2015) proposed a pattern generation algorithm for men's jacket according to the types of body surface development figure. Jeong (2018) developed a tight-fit pants pattern based on body surface change and garment pressure evaluation using 3D scanning and modeling technology. Shin and Suh (2019) developed a men's formal jacket pattern by 3D human body scan data.

3D human body shape modeling. In the early steps of the development of 3D anthropometric measurement technology, it was mainly focused on quantitative measurement of the human body, but a more complete form of human body model was required as the scope of application gradually expanded (Kim, 2008). The 3D human body modeling data can be used for dummy for garment production, and furthermore, it can be used as a virtual fitting tool that can check the clothes wearing status online through the construction of a parametric virtual human body.

A dummy for garment production is an essential element in the apparel industry ranging from pattern making, sample making, and inspection of clothing. Alvanon, a world-class dummy manufacturing company for garment production, is developing a dummy by modeling standard body types using 3D scan data and providing files compatible with most 3D garment simulation programs as shown in Figure 4.

Choi and Nam (2008) reported that accurate fit can be evaluated by developing a body that reflects an individual's body shape using 3D scan data. They also suggested that both rotation of scan data and surface smoothing is key to processing raw data of 3D human body shape. According to the study of Nam et al. (2004), it was revealed that errors in

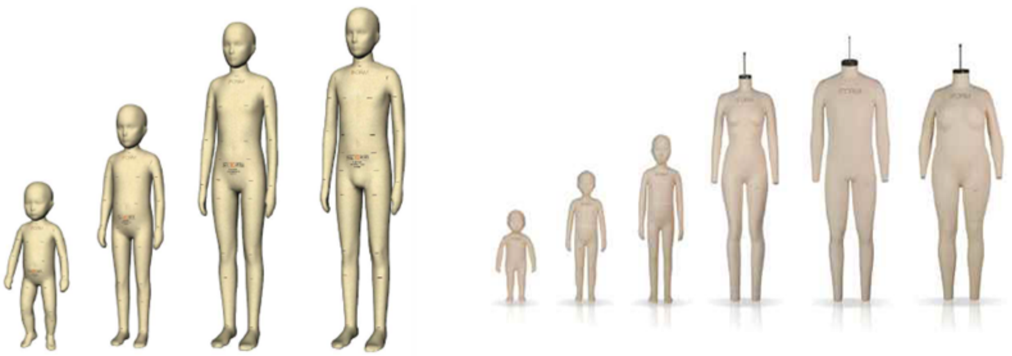

Figure 4. Virtual mannequin (Origin: http://alvanon.com/what-we-do/supply-chain-tools/)

3D human body measurements occurred by holes or very rough surfaces resulting from the unmeasured part of the human body scans depending on the body scan posture.

As above mentioned, the application of 3D human body scan data is increasing in various areas of clothing design, and it also has a great ripple effect throughout the industry. While previous research has focused on the development of hardware technology such as the improvement of scanner precision and scanning speed, it is expected that the technological advance in the future would increase the quality and range of application of the accumulated 3D data. Therefore, in this study, as a basic study for designing a more complete human body model, the 3D human body scan data editing process is defined and error factors for each editing process are investigated. Accordingly, in this study as a basic study for designing a more complete human body model, a 3D human body scan data editing process is defined and error factors for each editing process are investigated.

Method

Five adult females in their 20s, who corresponded to 'normal' obesity criteria based on BMI ranging from 18 to 22.9, were participated in this study and 3D human body scan data were obtained using a contactless 3D scanner, Hamamatsu's Body Line Scanner. The shape of the 3D scan data was analyzed using the Rapidform 2006, which is a 3D reverse engineering modeler.

By observing the raw data of the 3D human body scan data, the necessity of standardization of the 3D human body shape editing process for clothing design was investigated, and the 3D human body scan editing process for clothing design was defined, and the error factors for each editing process were analyzed. With Rapidform 2006 program, we defined the error factors that can occur during the restoration of unmeasured 3D human body parts, 3D axis selection, surface smoothing treatment, quality management of 3D shape mesh, and left and right symmetric shape creation process.

Result

Investigation on the necessity of editing 3D human body scan data

The 3D scan data of an adult female in her 20s using the Hamamatsu's Body Line Scanner is shown in Figure 5. As a result of analyzing the scan data using the RapidForm 2006 program, it was revealed that large areas of the unmeasured area occurred on the top of the head and the thigh, which are horizontally irradiated with the laser. This result is consistent with the analysis of previous studies investigating the principle of the scanner, that 3D human body scanners generate unmeasured areas in areas where the laser does not reach as the laser is irradiated horizontally. Such an unmeasured area becomes a factor limiting the utilization of 3D scan data, and serves as a critical error factor in extracting accurate human body dimensions from 3D scan data. Therefore, there is an urgent need for standardization and definition of editing methods for unmeasured areas.

The left side of Figure 6 refers to a frontal observation of 3D human body scan data using the RapidForm 2006 program. In the pattern construction for clothing design, only half of the pattern is drafted under the assumption that the left and right sides of the human body are symmetrical. Accordingly, the shape is completed by inverting the right or

Figure 5. Unmeasured part of 3D human body scan data

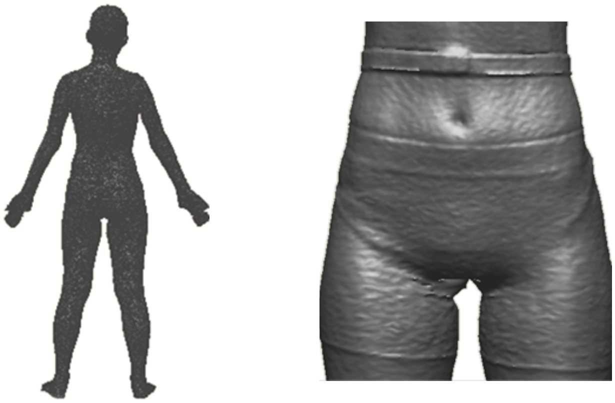

Figure 6. Shape of 3D human body scan data

left shape suitable for the purpose of the study based on the canonical plane of the human body, which results in a large difference in dimensions and shapes even if the axis of the canonical plane is slightly misaligned.

Choi and Nam (2008) reported that the rotation of the scan data is necessary as a process to minimize the size change in the process of making the body in the form of left-right symmetry. Since the front reference axis of the human body shape data varies depending on the scanner model and calibration conditions, it can be confirmed that the human body shape rotation is an essential process in the editing process of the human scan data.

The right side of Figure 6 shows the result of observing the surface irregularities of 3D human body scan data. Surface irregularities caused by the characteristics of 3D scanners and surface irregularities caused by wearing of measuring suits and measuring belts cause errors in human body measurement (Nam et al., 2004). Therefore, surface editing of human body scan data must be performed. In addition, surface editing of human body scan data must be preceded for the development of a 3D dummy to be utilized in virtual fitting programs and online shopping malls. In order to edit the surface of the 3D human body scan data, it is necessary to control the quality of the mesh within a range that does not change the shape characteristics and dimensional characteristics of the 3D human body scan raw data. If the file size is too large due to an excessively high-density mesh, it is necessary to reduce the number of mesh points and enhance the mesh quality by uniformly aligning unevenly aligned meshes, as the loading and computation speed is too slow in the program after 3D modeling.

Definition of 3D human body scan data editing process

In the study of Hlaing et al. (2013), a 3D virtual dummy was developed to design a clothing pattern using the virtual dummy, and the process is summarized in Figure 7. Except for step 2 and 3 of selecting data appropriate for the study,

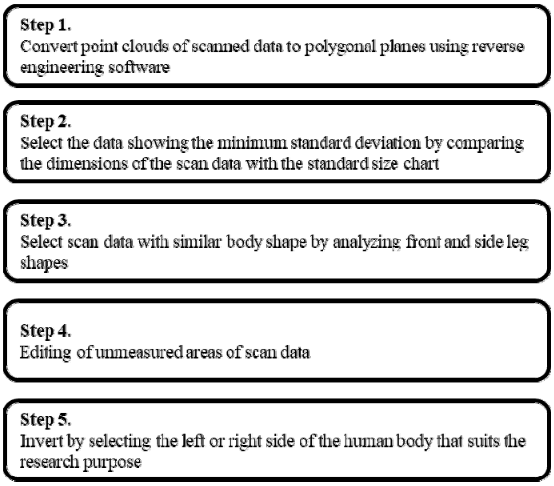

Figure 7. 3D virtual dummy development process (Hlaing et al., 2013)

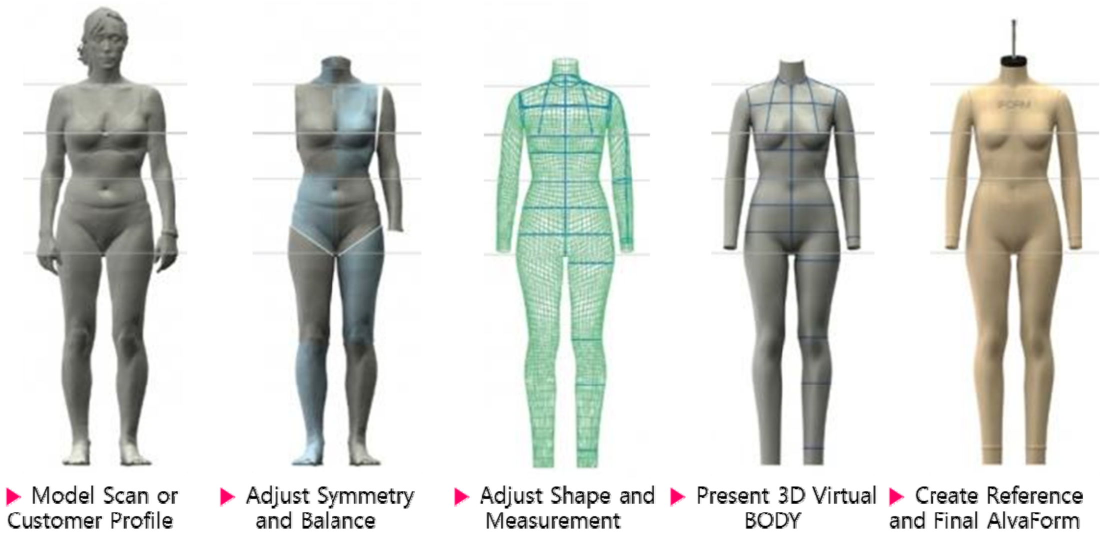

Figure 8. The 3D body modeling process of Alvanon, Inc.

3D human shape editing process is divided into the process of editing the unmeasured part and the process of completing the left-right symmetric model.

Figure 8 shows the 3D body modeling process of Alvanon, Inc. After reversing the 3D human scan raw data to the left and right, editing it into a symmetrical model, combining it, and then A 3D body virtual body is finalized. According to the editing process of the 3D human body scan data, it can be noticed that the process of inverting the left and right sides is essential for the purpose of designing clothes. However, the utilization and comparison of each model are somewhat limited since the 3D human body models are being developed without standardization of the data rotation method to minimize the dimensional change in the process of inverting left and right.

In this study, the 3D human body scan data editing process was proposed as shown in Figure 9 according to the need for editing derived by analyzing raw data previously scanned for adult women in their 20s and the research findings of previous studies.

The first step is a process to align the axes through rotation of the scan data in order to minimize changes in human body dimensions. In step 2, the quality of the human body shape is improved by restoring unmeasured part of the scan data with the axes aligned. In step 3, the unevenness of the surface is arranged smoothly. In step 4, the number of mesh points is reduced to improve the data processing speed by reducing the size of the scan data, and then the randomly arranged mesh is rearranged to enhance the mesh quality. In the last step, the right or left side suitable is selected for the purpose of the study and inverted based on the canonical plane of the human body. Then, the shape editing is finalized so as to make a symmetrical shape.

Step 1	**Rotation of scan data** A process to minimize the change in dimensions of the shape in the process of reversing the left and right
Step 2	**Fill hole of unmeasured area** A process to reduce measurement errors and improve shape quality by restoring unmeasured areas
Step 3	**Surface editing of scan data** Process to improve shape quality by arranging the surface of scan data smoothly
Step 4	**Mesh editing of scan data** Process to improve the quality of scan data by reducing and rearranging the number of mesh points
Step 5	**Reverse the left and right of scan data** The process of making shapes symmetrical for clothing design

Figure 9. A proposal for standardizing the editing process of 3D human scan data

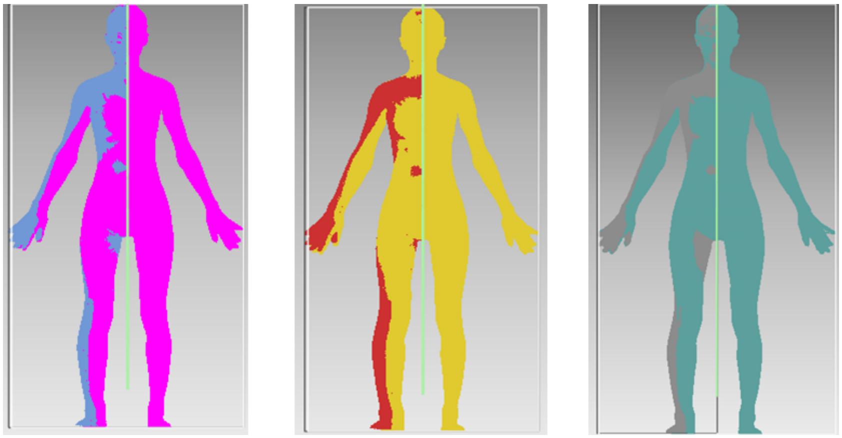

Figure 10. Error occurs in the rotation step of scan data (Left by Axis: After Editing, Right by Axis: Origin)

Error factors for each editing process of 3D human scan data

Factors causing errors in scan data rotation. If the axis is not properly determined in the first step of the editing process, the rotation step of the scan data, the fifth step, the error occurs in the inversion process of the scan data. Figure 10 shows the result of editing the data by varying rotation angles with the same scanned data, overlapping it with the original data, and verifying the voids. It is revealed that only a slight difference in rotation angle may exhibit different results after reversing the shape. Therefore, when editing human body scan data by reversing the shape, the difference in shape change must be checked after the scan data is inverted and then overlapped with the original shape. It is imperative to verify that there is no difference from the original dimension by checking not only the shape but also the dimensional change.

Factors causing errors in the editing step of unmeasured parts of scan data. The 'Fill hole', provided in the Rapid Form 2006 program, is a tool for editing the unmeasured part of the human body. ‘Fill hole’ provides four options along with the principles as shown in Table 1. Depending on the selection of the peel hole function, there is a difference in the restored shape, and this difference also affects the dimensions of the human body, so it acts as a factor that causes the largest error in the 3D human body scan data editing process. Therefore, standardization and optimal options of editing method for each part must be defined.

Factors causing errors in the surface smoothing and mesh editing of scan data. The 'Smooth', provided in the Rapid Form 2006 program, is a tool for leveling the surface irregularities of 3D human body scan data. Depending on the weight option, there is a difference in the capability to smooth the surface, as well as reducing or enlarging the shape by adjusting the + and – options. Therefore, since the dimensions can vary with difference in weight options, it will be necessary to try to minimize the error through methods such as limiting the weight options or limiting the difference between the finished shape and the original shape.

Table 1. The principles of each function of Fill hole

Option	Principle
Flat	Fill the unmeasured area flat with polygons.
Smooth	Fill the unmeasured area smoothly with the surrounding mesh.
Curvature	The unmeasured area is filled by reflecting the curvature of the surrounding mesh.
Bridge	If the unmeasured area is wide, form a bridge and fill it by reflecting the curvature of the bridge.

In the step of editing the mesh of the 3D human body shape data, the file size is reduced by reducing the number of mesh points to facilitate compatibility between programs. In addition, the number of mesh points can be adjusted using the 'Decimate' tool. If the number of meshes is reduced too much, attention should be paid to the fact the distance between meshes increases so that the shape is simplified as shown in Figure 11. In order to reduce errors in the mesh editing step, care must be taken not to deform the human body shape by limiting the ratio of mesh points that can be reduced from the overall shape of the human body.

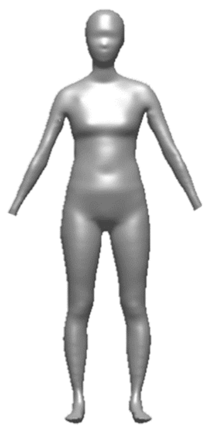

Figure 11. Simplification of shape after mesh point reduction of scan data

Conclusion

The 3D human body scan technology continues to grow and related hardware continues to develop around developed countries. With the development of these technologies, the spread of 3D human body scanners is accelerating and their utilization is increasing. In this study, as a basic study for designing a more complete form of the human body model, the 3D human body scan data editing process was defined, and error factors for each editing process were investigated. To this end, a novel 3D human body scan data editing process was proposed and error factors were analyzed for each editing process so as to increase the utilization of the 3D human body scan data.

According to the result of the study, it was confirmed that the 3D human body scan raw data inevitably causes unmeasured parts due to the measurement principle of the scanner. These findings are consistent with those of Kim and Hong (2009) and Park (2012), who pointed out unmeasured parts as factors of error in the editing process in clothing design studies using 3D human body scan data.

In this study, not only the unmeasured parts of the 3D human body shape, but also the error factors for each 3D body shape editing process were defined to enable standardization of the 3D human body scan data editing process for clothing design. In order to satisfy the requirement as a 3D human body model for clothing design, it is necessary to make the shape data symmetrical left and right. At this time, errors that hinder clothing design may occur such as changing body dimensions due to rotation angles. In addition, errors also occur in the process of both smoothing surfaces and editing meshes to enhance the quality of the 3D human body shape. In order to minimize these error factors, we proposed a novel 3D human body scan data editing process consisting of the steps of rotating the scan data, editing the unmeasured area, smoothing the surface of the scan data, editing the mesh of the scan data, and reversing the scan data. According to the analysis of error factors in each editing step using the RapidForm 2006 program, errors in reversing scan data and errors in the editing step of the unmeasured part were identified as the dominant error factors. Furthermore, it was confirmed that errors may occur in the shape and dimensions even in the editing step of the surface shape and mesh of 3D human body scan data. Consequently, it was suggested that additional efforts for the standardization of 3D human body scan data editing are required.

This study is a basic study to standardize 3D human body scan data and improve the quality of scanned data. Research findings relating to the editing process and error factors are expected to increase the utilization of 3D human body scan data. Since this study has focused to derive the error-generating factors, it is recommended that subsequent studies would be conducted to suggest the optimal editing method for each error factor identified from this study.

References

Choi, Y. L. & Nam, Y. J. (2008). *A study of methodology developing reconstructed body using styrofoam boards. Fashion & Textile Research Journal, 10*(5), 713-720.

D'Apuzzo, N. (2007). 3D body scanning technology for fashion and apparel industry. *Proceedings of SPIE-The International Society for Optical Engineering, 6491*.

Han, H. S. (2007). *(A) Study on the automatic setting of 3D body landmarks and measuring paths for apparel* (Unpublished doctoral thesis). Seoul National University, Seoul, South Korea.

Hlaing, E. C., Krzywinski, S., & Roedel, H. (2013). Garment prototyping based on scalable virtual female bodies. *International Journal of Clothing Science and Technology, 25*(3), 184-197. doi: 10.1108/0955622131 1300200

Jeong, E. Y. (2018). *Development of tight-fit pants pattern based on body surface change and garment pressure evaluation using 3D scanning and modeling technology* (Unpublished master's thesis). Yeungnam University, Daegu, South Korea.

Ju, S. L. (2003). Current state of 3D human body shape measurement. *The Monthly Technology & Standards, 17*, 8-16.

Kim, I. H. (2015). *Development of a pattern generation algorithm for men's jacket according to the types of body surface development figure* (Unpublished doctoral thesis). Seoul National University, Seoul, South Korea.

Kim, K. S., Nam, Y. J., & Han, H. S. (2016). A study on the automatic measurement of 3D body angle for apparel. *Korean Society of Basic Design & Art, 17*(5), 73-82.

Kim, M. S. (2018). *Development of a script based universal three-dimensional body measurement system* (Unpublished master's thesis). Seoul National University, Seoul, South Korea.

Kim, S. & Hong, K. (2009). Comparison of the editing method of missing area in 3D scanned image of men`s crotch. *Journal of the Korean Society of Clothing and Textile, 3*(3), 401-409.

Kim, S. M. (2008). Overview and applications of 3D anthropometric technology. *Fiber Technology and Industry, 12*(4), 268-273.

Lee, S. W., Kim, G. J., Nam, Y. J., No, H. S., Jung, M. S., Choi, K. M., & Choi, Y. K. (2002). *Clothing morphology*. Seoul: Kyohak Research Institute.

Nam, Y. J., Choi, K. M., Jung, E. S., & Yun, M. H. (2004). Standardization of 3D body measurement for the size Korea. *Fashion Information and Technology, 1*, 6-19.

Park, C. G. & Kim, S. M. (2004). Digital fashion textile products using 3D and virtual space technology. *Fiber Technology and Industry, 8*(1), 30-42.

Park, S. M. (2012). A study on the automatic measurement of 3D body angle for apparel. *Korean Agency for Technology and Standards*. Retrieved from https://www.kats.go.kr/content.do?cmsid=302&searchField=title&searchValue=%EC%A0%9C31%ED%98%B8&y=0&x=0&mode=view&page=1&cid=13421

Shim, B. J. (1996). *Clothing ergonomics*. Seoul: Kyohak Research Institute.

Shin, K. H. & Suh, C. Y. (2019). A study on development of men's formal jacket pattern by 3D human body scan data-A focus on men's in their late 30s-. *The Korean Society of Clothing and Textiles, 43*(3), 440-458. doi: 10.5850/JKSCT.2019.43.3.440

Yoon, S. H., Hyun, D. E., & Kim, M. S. (2004). New techniques for measuring 3D human body sized and shape deformation. *Fashion Information and Technology, 1*, 6-19.