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Original Article

Experiencing Body Scan and Computer Simulation Virtual Fitting

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Abstract *- This research explored using personal avatars (from body scanning) as fit models. Also, this project is to explore fitting accuracy through the use of personal avatars and examining outcomes. Researchers who had 2D/3D computer-aided design skills developed two basic garments and virtually draped the garments on two avatars, one was the software program's default avatar, and the second was a personal avatar captured through a 3D body scan. The garments were also assembled in muslin and fit during a live session. Photographs of the three scenarios documented the static fit of the garments. Overall, the participants were satisfied with evaluating the virtual garment on their avatar, though disappointed that the avatar itself was not a cleaner image. There was some difference in the fit results between the personal avatar and the live session due to fabric appearance and differences in draping. Further research, and advancement in virtual textile rendering, need to take place as this affects the visual fit of the avatar. Virtual fit has the potential to be a time- and cost-saving practice for the industry.*

Keywords *- Body-scanning, Fitting-simulation, Avatars, Structure, Virtual-Fitting.*

1. Introduction

This research compared the fitting differences between a personal avatar simulation, a generic computer avatar and a live fitting to explore fitting accuracy and examine outcomes which can be useful for researchers and industry and guide future directions of computer fitting simulations. By adopting technology, both small and large retailers could increase sizing accuracy and gain consumers' trust, thereby increasing profits.

Currently, garments are developed through either flat pattern or draping techniques based on sample size determined by each company. The initial garments are stitched by sample makers individually and fit a static dress form for an initial review of fit and style. Once approved and any needed alterations are completed, the garment is placed on a live fit model. Industry fit models are individuals whose measurements accurately represent the company's target population. They are rarely "perfect" on every measurement, but the main measurements and proportions match. The fit model is used for a few main reasons; for example, they can give verbal feedback if the garment feels tight, is loose, hard to close, or has other issues and when there is a lack of visual cues to determine the issue. Also, there are times when the garment should be fit on an active individual - sitting, reaching or other activity can be evaluated accurately through a fit model.

Retail sales of women's clothing in the United States were approximately $41 billion in 2018. However, there is a high level of garment returns, the most common reason being poor fit [1,2]. Apparel fit is the most important attribute for consumers in determining overall satisfaction with apparel purchases [3]. Therefore, if the apparel industry can find valid methods to help improve the fit of garments for their target market, it could increase profits significantly.

2. Fitting Apparel

Industry fit experts analyze the fit of clothing on a live fit model in a standard size based on their chosen target market. However, every human body does not come in standardized sizes and finding the best fit for any apparel item can be difficult. Indeed, this is one aspect of the industry which researchers have tried to improve since the O'Brien and Shelton anthropometric study in 1941 [4].

Many research studies have suggested that standardized garment sizes do not satisfy consumers and cannot provide a good fit regardless of race or age group [5]. Experts agree that fit issues are the top reason customers return online purchases [6, 7, 8]. Consumer surveys and return rates confirm that poor fit is the main reason for apparel returns; between 35% and 50% of female customers in the United States have found the fit of apparel not to meet their expectations [8,9]. Fit is the most important factor (78%) for many women in purchasing an apparel item [10]. Indeed, returns are one of the main reasons that retailers hesitate to expand their online offerings.

2.1. Apparel and Sizing Standards

2.1.1. Sizing Standards

Sizing standards, such as the ones published by the American Society for Testing & Materials (ASTM), are largely based on outdated body measurement studies, historical data and customer feedback. These systems are based on grouping measurements to create an approximate body, aiming to "fit the maximum number of people with the minimum number of sizes" [11]. Current sizing systems do not fit the entire population, as typically, only 50% of the population is covered by a standardized system of sizes [12].

In traditional garment making, a muslin sample is used to examine fitting on a standard dress form by an experienced dressmaker/patternmaker. Companies use a live fit model that corresponds to a specific size that they feel mimics the size and shape of their target market. Typically, this is a misses' size 8 or 10. A team consisting of patternmakers, designers, and product development experts analyze the fit on the live model, makes alterations based on their chosen target market and personal experience and then signs off or approves the production of the garment once a satisfactory fit has been achieved. Due to the costs associated with developing, fitting and altering a garment, companies only create one sample size leaving them with a small size range which fits adequately.

Even with experts, this method does not guarantee a good fit for everyone. Standardized charts are developed for specific body proportions. Desmarteau and Speer (2004), referring to a Kurt Salmon Associates study, stated that "50% of women ...cannot find a good fit in apparel and other studies have shown that 50% of catalog returns are because of fit problems" (p. 28) [8]. The industry has struggled with sizing standards and grading rules. Schofield and Labat (2005), in their research on the grading of women's bodices found 6 false assumptions in the grading rules used by industry [12]. They also found that the assumptions made for the main circumference measurements of the body, mainly the bust, waist and hips, are not constant for all sizes, as is assumed in the industry sizing tables.

Using the size indicated on the apparel item does not help the consumer determine fit. "One of the problems with apparel sizing is... that numerical size labeling has no real meaning for many female consumers" (p. 202) [13]. Vanity sizing, the practice of manufacturers who use smaller size labels on clothing than the measurements indicate, is also at fault here and creates additional confusion to the question: *what size am I?*

2.1.2 Fitting Issues

The clothing retailer Amazon announced the use of body scanning to reduce major returns due to fitting issues after acquiring the start-up company Body Labs in 2017 [14]. Their objectives in body scanning and avatar creation were to improve garment fit, increase consumer satisfaction, and increase the use of virtual fitting simulation before clothing is manufactured or shipped out. Body scans can generate a personal size model for an individual's avatar for customers to self-assess for fit and style. Conversely, online consumers demand online fitting opportunities, including fitting methods and accurate measurements.

Product visualization techniques, such as a personalized avatar, also increase the entertainment value of shopping online [15]. This study found that while consumers liked the entertainment aspect of virtually trying on a garment, they lacked confidence that this technology provides reliable information regarding fit. One participant in the Kim and Forsythe study (p. 51) commented on the personalized avatar stating, "For fun, I will do it, but it doesn't provide me with a whole lot of information...the clothing doesn't look realistic to me". Although many websites provide online virtual fit, these tools are not yet useful for accurate fitting but mainly for two-dimensional virtual observation [16].

Currently, there are several applications (apps) such as Sizer ©, MySize ©, FitFinder © and Selfie Styler ©, all of which promise to give consumers their correct size in specific brands. These apps use a variety of methods to complete their size prediction. FitFinder uses consumer-driven information on height, weight, belly shape and fit preference. Selfie Styler spent a few years developing a size prediction algorithm from front and side views of a consumer to predict measurements from a photograph. MySize requires the consumer to move their iPhone to specific sections on their body to allow the app to measure the body by placing your phone directly on these areas. All apps promise reduced returns, but none have reached full immersion in the marketplace. Researchers have proposed the 3D personal mannequin to replace generic dress forms to reflect standardized and personal measurements for testing fit [17]. Some researchers have adopted data-driven 3D reconstruction of human bodies to simulate a dress form [18]. By using standardization of size and shape, researchers can create virtual human bodies for apparel products [19].

2.2.1. Body scanning

Many countries have conducted anthropometric studies using 3D body scanners to create a database of body measurements for various purposes, including the fit of clothing. The United Kingdom was one of the first to conduct a survey when they created the organization SizeUK in 2001 [20]. Since then, we have seen many other countries and companies follow suit, which includes

SizeUSA in 2003, SizeThailand (2008), Sizing Up Australia (2009), SizeNorthAmerica (2019) and others. Regularly updating body scan data is important to identify changing body sizes and shapes to develop properly fitting garments for consumer purchase satisfaction.

3D body scanning technologies offer anthropometric data, body surface area and body volume for evaluating the differences or changes in body shape in health and sports sciences [21]. For comfort during body movement, 3D body scanning can also be used to evaluate the air gap and garment sliding situation during the body movement [19].

2.2.2. 3D Body Scanning

Body scanning technology has been available commercially since the late 1990s [22]. Early scanners were large, cumbersome and, most importantly, stationary. While some were considered portable by the manufacturer, it took 3 - 4 people to assemble/disassemble, and a large cargo van or truck was needed to transport them. These early scanners were mostly used for anthropometric studies such as Size USA (2003) but also for custom manufacturing, suggesting apparel sizes and the development of personal avatars [22].

Body scanning has come a long way since the late 1990s. Commercial body scanners are smaller, but current technology also allows body scanning with an iPad or phone application, though with less accuracy. Body scanning allows for quick and accurate measurements of a three-dimensional object in a very short time, typically in seconds. It can also capture the garment’s relationship to the body, or the ease of a garment, accurately in a 3D image [23]. Body scan data is generated as a point cloud from which a computer extracts information to build surface details and can identify body landmarks to generate measurement data.

Many formats of capturing a body scan (i.e., photogrammetry, laser, white light, microwave) can develop and provide 3D simulation models [24]. One example is the Human Solutions scanner which is based on laser technology and uses 4 dual camera sensor heads to acquire over 100 body measurements in 12 seconds through laser triangulation [25]. However, the footprint of most commercial body scanners is at least 4 feet square.

Traditionally body scanning is conducted once the participant steps into a scanning area or the area where the scanning devices (i.e., laser, white lights) can read the body. The participant must stand still in a set position while the equipment moves vertically, reading the body through fixed horizontal sensors. The scan begins when the participant pushes a button within the scanner, or another person initiates the scan on a computer monitor. While this body scanner is easy to operate, the fixed sensor only captures a fixed direction (horizontal) to obtain body data. It requires a software architect (typically automatic) to complete the model using mathematical modeling.

A handheld sensor, such as the Structure Sensor ©, takes longer to capture the body. Still, it can be adjusted to capture body angles and uneven body shapes to complete a more accurate simulation model (See Figures 1 and 2). Structure Sensors can capture data 360 degrees and move at various angles along with a curved body shape to capture different body parts. The structure is easy to adjust to capture at different distances.

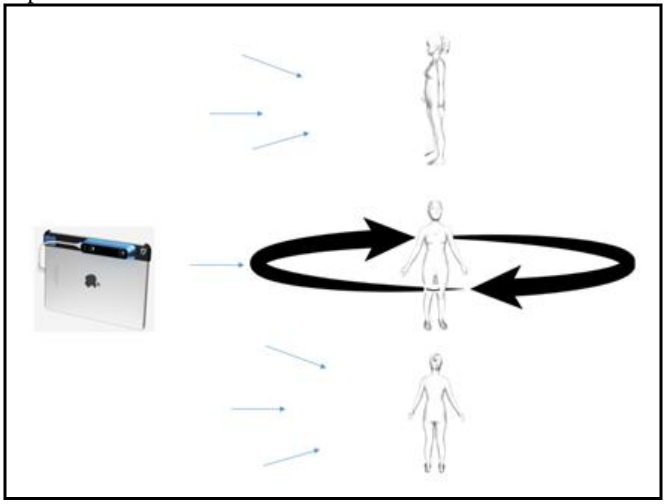


Fig. 1 Structure lens can be used to capture data in 360 degrees and can be moved in a variety of angles along with curved body shapes.

2.2.3. 3D Apparel Fit

When body scanners were introduced more than 20 years ago, they were often referred to as the solution to fit into the apparel industry [22]. Dress forms are manufactured using body scan data that can accurately depict the identical shape of a fit model. Designing clothing to fit a target population requires an understanding of the body shapes and sizes of the specific population. However, finding a good fit for everyone in the population is difficult as the human body varies greatly in all dimensions and combinations of length and circumference.

Even if the designer has accurate anthropometric information, achieving a good fit may still be difficult because body measurements do not translate easily into garment dimensions. Indeed, human variability is such that there are no correlated dimensions (length/circumference) and most sizing charts only fit a certain percentage of people [26]. Body measurements alone do not tell how the measurement is distributed on the body itself. For example, a 38” bust measurement does not tell the designers if the person is a C-cup or has a broad back.

Many researchers suggested that 3D virtual simulation technology can effectively visualize the fit and silhouette of apparel as well as products of mass customization [27,28].

Many styles, such as pants and other close-fitting garments, adopted 3D body scanning technology for fitting methods [29].

The avatar is a whole-body scanned visualization that replicates the user's body size and observed body shape. The measurements are more accurate than traditional hand-measuring with a physical tape measure. Adopting 3D body scanning to create 3D simulation models can replace taking body measurements in person with greater accuracy [30]. The resulting avatar and measurement information is retrievable for future use. Based on actual human bodies, these custom avatars can be used for accurate fitting purposes, including as fit models, made-to-measure, and mass customization for the apparel industry [31,32]. This research adopted 3D body scanning technology to create 3D simulation models as personal avatars that can be used to drape/simulation clothing for fitting evaluation.

3. Materials and Methods

3.1. Structure Scanner

Body scanning using an iPad with a Structure lens was adopted not only for its scanning accuracy but also due to its affordable price, ease of purchase and operation. The Structure Sensor captures body scans with infrared LEDs and a camera to measure and map 3D coordinates. The Structure Sensor is a mobile scanner; therefore, participant body scanning can be done in a location of choice, thereby increasing their comfort.

The apparel industry should have a minimum accuracy of ±0.5mm in choosing a scanner, at which point raw eye observation cannot detect the difference. The Structure Sensor provides a point maxima accuracy of 0.5mm for less than US$1,000 compared to more than US$2,500 or more to reach a maxima accuracy of 0.1mm [33]. This scanner integrates with other existing applications (CAD) in various file formats (STL, PLY and OBJ); therefore, it is easy to work between software programs. According to research reports, a body scan measurement average is within 1-6 mm of manual measurement for stature, head circumference and arm circumference [34, 35].

3.2. Procedure

Data from this project was collected from a fashion design program. The Product Lifestyle Management course requires students to have already passed a 2D/3D Computer-Aided Design course, and therefore students are familiar with clothing drape/simulation using a standard program avatar. This course's first project is based on production line development (mass production). The second project is a 3D simulation of a fit session so that students can experience fitting issues and develop their critical thinking skills.

The purpose of this project was four-fold. First, students in the 2D/3D CAD course were taught and executed 2D and 3D integrated pattern designs and 3D simulations. Students in the Product Lifecycle Management course learned to scan each other using an iPad with a Structure lens. The chosen model could be registered as a student in the course or a volunteer recruited by a student, such as a fit model. This class is an oral focus class; therefore, students must present three oral reports. One of the three oral presentations was on their fitting evaluation. The students each created a personal avatar based on their 3D body scan. This process included cleaning the point cloud as avatars need to be edited, particularly if there is a busy background or to clean the image. Also, students were required to check that their avatar is positioned in the center of the axis (i.e., the origin 0 with coordinate; x,y,z: 0,0,0) to coordinate with other software. With origin 0, the personal avatar could be used in the design program during the drape/simulation process [22]. Students then used a virtual fitting simulation activity to evaluate fitting issues on their or their volunteer's avatar.

As a practice, students viewed a pre-programmed avatar and conducted a fit session using two basic garments (skirt and dress). In preparation for their evaluation, students participated in a group critique using blind review. Examples of a volunteer wearing a muslin sample garment in real life were shown along with the same volunteer as an avatar wearing the same muslin garment. Separately, images of traditional muslin fitting tests were used to compare fitting differences with a virtual fitting evaluation. Therefore, the student had some knowledgeable guidance and actual fit experience before completing their personal avatar critique. There were two sections of the fitting evaluation. Section I compared the program and personal avatars with more than 100 students, while Section II was an additional in-person fitting evaluation. Participation in this study was voluntary, and there were 15 female college-age participants. Fig. 3 depicts the participants' body scanning project and fitting simulation.

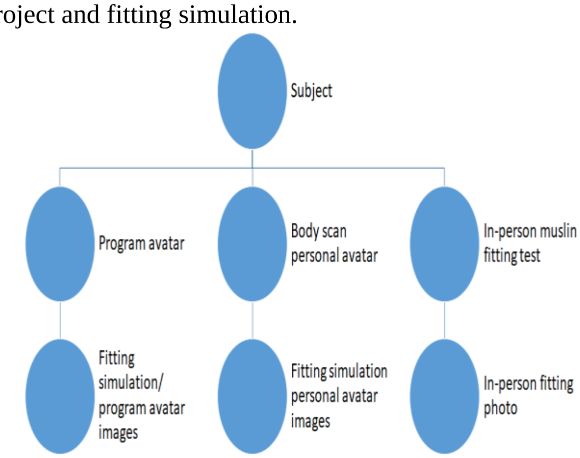


Fig. 3 Workflow comparison and evaluation of fittings based on three types of photographic images

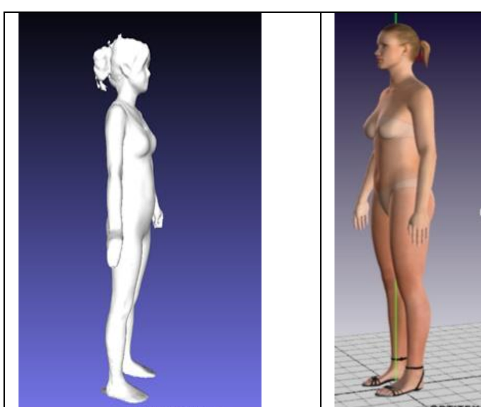
3.3.1. Body Scanning

The Structure Sensor, which attaches to an iPad, was the preferred method of capturing personal body scans. Once the body scan was completed, it was uploaded into Optitex software, and the avatar was made. A total of 3 images (i.e., front, back and side views) were used to compare and evaluate the fitting situations of a one-piece dress and a flared skirt. The following were the artifacts examined:

A. The two garments were placed on a personal avatar created in Optitex using their drape/simulation function,
B. Patterns of a one-piece dress and a flared skirt were digitized to conduct a clothing fitting simulation in Optitex on the program avatar,
C. Paper patterns of the same one-piece dress and a flared skirt were made with muslin to compare the fit on a live model.

There were three sets of 3 photographs. All photos of scenarios A, B, and C were used to compare and analyze fitting differences and fitting issues (i.e., a smooth look with no pulls or wrinkles, no sagging or baggy areas, and the evenness of hem and hem with waves) between the three methods. Figure 4 shows a personal avatar from 3D body scanning and a program avatar from Optitex software. The first image is a personal avatar body scanned using the Structure Sensor with the subject wearing a non-compressing bra and tights.

Body scanning using an iPad with a Structure lens was adopted due to its affordable price, ease of purchase and operation. Participants were all body-scanned using the iPad with a Structure lens. Following the scanning process, subjects responded to a 20-item questionnaire about the process and resulting avatar. Overall, participants expressed satisfaction with their avatar and body shape.



Personal avatar viewing via Meshlab | **Program avatar** viewing via Optitex

Fig. 4 Personal Avatar and Optitex Avatar

3.3.2. Personal Avatar

To produce a personal avatar by using body scanning, the dress code was set as sleeveless and collarless, very close-fitting clothing (non-compressible short pants), with a preference for exposed arms and legs. Skanect software develops the images collected by the Structure Sensor into a full-colour, 3D model or avatar. Subjects must first open the Structure Sensor app on the iPad, then the Skanect program on the computer. Settings for Skanect have to be adjusted every time they open the program. For this project, the participants found that the bounding box was most effective at around 0.6 meters, and the scene setting should be changed to object. Once the Structure Sensor is synced with the iPad, the light turns green to show that the connection has been made. One issue that came up is that the user must be sure that the Structure Sensor and the computer are on the same wifi signal to sync. Once the sync is complete, the operator can start the scanning process.

To capture the body scan, the scanner operator (being held by a secondary researcher) must move completely around the fit model/participant/volunteer being scanned (360 degrees), and the fit model (subject) needs to be as still as possible. There is a platform for the fit model to stand on, as well as two metal rods for the participant to brace themselves with to reduce movement. The scanner operator must direct the scanning lens up and down the body and make sure it recognises all body parts. The scanner operator should go somewhat slowly, resulting in greater detail and accuracy.

3.3.3. Preparing Simulation

Preparing the avatars and the clothing drape/simulation is a long and complex process. The program MeshLab was used to view, edit, and measure the personal avatar, which was created using the iPad with a Structure lens. MeshLab, an open source and free 3-D visualization software, was used to process and edit the 3D meshes or point clouds. It is free to download and available to everyone.

The body scan is converted to a personal avatar, at which point it can be viewed and edited in the MeshLab. Editing an avatar can be challenging; therefore, participants were instructed to advance their technical skills and prepare the avatar for the fit simulation. The program MeshLab was used to view, edit, and measure each personal avatar. Three MeshLab-related videos on editing were also developed specifically for this project and made available to share with the public.

The 3D body scanning process also captures objects near the environment; therefore, these unwanted objects must be removed and cleaned before moving forward with the fitting simulation. The unwanted objects in the near environment create difficulties during the drape/simulation process.

Once the unwanted objects around the personal avatar are removed, the personal avatar needs to be set in the center of the axis (x, y, z; 0,0,0) to prepare for the fitting simulation. This procedure was the most challenging of the entire project. It required more time and patience on the part of the participants.

3.3.4. Computer simulation

Researchers prepared their personal avatars for the final goal of conducting a fit test. Once the personal avatar is prepared and ready, using the Optitex program to conduct clothing drape/simulation is a straightforward process. Each participant selected the proper fabric properties, digital garment pattern, and textile design within the Optitex program. Then they input assembly directions for the software to assemble the garment with the chosen attributes. Once the garment is complete, participants are ready for the fit analysis.

4. Results and Discussion

4.1. Results and Evaluation

Researchers used a worksheet to assess the fit of the two garment styles. They were told to look for ill-fitting areas of the garment by making notes of wrinkles, sagging fabrics and bagginess. The hem area was to look even and without excess dips or waves. It was done for the front, side and back views. Researchers were asked to make additional notes concerning posture. Note that each image shows a straight, vertical line which helped to evaluate fitting horizontally from the shoulder, waist and hem. Figures 5 and 6 show the worksheets the researchers used to complete that fitting evaluation in the proper sequence.

4.2. Evaluation

Using fit simulation technology and personal avatars, more than 150 student participants conducted a virtual fit session with standard size patterns altered for a personal fit. This fit simulation helped participants visualize their appearance when they wore the actual garment. Participants reported the virtual fit simulation resembled their bodies and was an accurate experience that they would appreciate being able to use in the future. Participants also reported that the procedure was clear and accurate, and results were displayed quickly. Basic alteration skills were also taught to improve the fit simulation on the personal avatar. Researchers selected and prepared two garment styles in muslin for 15 participants to try on and compare the fit to their avatar.

Overall, participants were satisfied with evaluating virtual clothing on personal avatars during this fitting simulation. On the other hand, some participants indicated dissatisfaction with the body scan avatar as it was not a clean image, having a lot of lumps on the areas of thighs and arms. This occurred mostly because the arms and legs were too close to the body, preventing the fabric's normal fall on the body scan avatar. Participants also commented on the difference between the speed of fitting a standard size avatar with one click and conducting a fitting simulation on a personal avatar which can be time-consuming due to body shape variations.

4.3. Evaluation Process

Each garment was given identical attributes; the grainlines, fabrication, and stitching lines of the computerized garment version matched the fabric samples. The grainlines were kept vertical to the body running from head to feet. Both simulations, personalized and standard avatars, were given fabric attributes to mimic the muslin fabric of the garments. The live model wore basic brief undergarments, an unpadded bra and no shoes. As the patterns were identical in all cases, the stitching lines remained the same throughout. The skirt was a basic flared skirt with a wide waist yoke. The sleeveless dress gathers at the front waist to accommodate the bust, has a midriff, and the skirt falls straight with dart shaping from the waist to the hips. The instructor constructed the garments to maintain quality.

A good fit is characterized by garments which follow the shape of the wearer's body with no points of stress, indicated by wrinkles. On a traditional woven garment, the shoulder seam should sit properly on the shoulder. The curves at the neck, armscye, waistline and hips follow the body's contours without tightness or sagging. The fit of a garment is one of the most important aspects of the purchasing decision. It is therefore important to develop a sample garment in the correct fabrication with the stated garment measurements and construction details.

The resulting garment is first evaluated on a mannequin or static model, which can give basic information on fit based on the presence or absence of such visual cues such as wrinkles (tightness), sagging (too loose) or bagginess (oversized). The fit assessment should start at the top of the garment and work down to the hem. For the flared skirt, it is very important to observe the evenness of the hem. Participants were asked to compare the fit between the three modalities of computer avatar, personal avatar and live session using the same two garments. Figures 7 and 8 show photographic examples of each method. For the avatars, a screenshot of the front (F), back (B), and side (S) of the garment were taken for this comparison, and the same images were taken of the live model. Students in all three views analyzed the images.

Following the development of avatars and garment designs, the design professionals rated the view of the Front, Side and Back of each avatar on Appearance, Smoothness, Fit, Balance and Seams on a scale of 1-10, with 1 being "Unsatisfied" and 10 being "Satisfied". Three design professionals evaluated the outfits of self-avatar and program-avatar. The evaluators' ratings, including the following styles: A-line Skirt and Sleeveless Straight Dress, were listed in Tables 1 and 2.

Fig. 5 Skirt fitting evaluations: Flare skirt example A.

Table 1. Results of A-line skirt evaluation

	Personal avatar				Mean	Optitex avatar				Mean
Appearan	F S B	10 9 7	10 9 7	9 9 10	**9.6** **9** **8**	F S B	10 10 10	10 10 10	10 10 10	**10** **10** **10**
Smoothnes	F S B	9 9 9	10 10 10	9 9 9	**9.3** **9.3** **9.3**	F S B	10 10 10	10 10 10	10 10 10	**10** **10** **10**
Fit	F S B	9 9 9	10 10 10	10 10 10	**9.6** **9.6** **9.6**	F S B	10 9 9	10 10 10	10 10 10	**10** **9.6** **9.6**

Note: F= Front view, S=Side view, and B=Back view

Fig. 6 One-piece dress fitting evaluations: Dress example B.

Table 2. Results of Women's Dress evaluation

	Personal avatar				Mean	Optitex avatar				Mean
Appearan	F S B	10 9 7	10 9 7	9 9 10	**9.6** **9** **8**	F S B	10 10 10	10 10 10	10 10 10	**10** **10** **10**
Smoothnes	F S B	9 9 9	10 10 10	9 9 9	**9.3** **9.3** **9.3**	F S B	10 10 10	10 10 10	10 10 10	**10** **10** **10**
Fit	F S B	9 9 9	10 10 10	10 10 10	**9.6** **9.6** **9.6**	F S B	10 9 9	10 10 10	10 10 10	**10** **9.6** **9.6**

Note: F= Front view, S=Side view, and B=Back view

4.4. Discussion

This study has shown that the student participants successfully conducted an accurate fit test in three modalities. Actual scans accurately replicate body proportions, posture, symmetry, and other spatial relations. Scanners also can scan the body in different positions, which could mimic active postures for fitting purposes. The industry could create an avatar based on a current fit model, which would immediately give them access to a fitting session without the wait time or extra cost of scheduling a live model. The avatar image could also be captured while wearing a specific garment so that anyone could refer to it in the future.

5. Conclusion

Computer simulation for virtual fit allows quick pattern alterations for fit or style purposes. For example, a long sleeve dress was designed, and the buyer wanted the same dress body but with short flutter sleeves. Instead of having a sample maker create an entirely new garment in a week, they could make the alterations within the software and generate a new garment within a few minutes.

However, some issues may need to be resolved before the industry adopts this fitting method. First, while many software companies are working on draping fabric on avatars, this is not yet perfected, and the differences could change the fit assessment of the garment. Small details are often not clear, even when the area is enlarged. It is also a new concept that would need to be adapted by industry professionals skilled at fitting garments to live models. Accuracy may be off as they learn the new software and how to identify fit issues.

Another issue may be with the accuracy of the avatar. Some software programs "smooth" out the algorithms that create the avatar, which slightly changes the accuracy of the model. If the designer uses different software for the pattern and animates the avatar, it would go through the smoothing process more than once. While small in actual measurement, it could mean a big difference in fit.

Research suggests that consumers express readiness to use avatars to try on clothing when the avatar's body size appears close to their size. Using personal avatars appeals to consumers who envision various applications such as monitoring health, taking exercise classes, clothing selection, and as an entertainment activity. E-commerce retail businesses can adopt virtual fitting rooms for virtual try-on as part of a business strategy to improve consumer satisfaction in terms of fit.

Product development teams should be trained to master current software to use modern 3D body scanning and the industry's future direction. Apparel manufacturers can reduce their risk of producing garments with fitting issues and reduce returns due to poor fit. This body-scan project can apply to any age group and enable businesses to be on the cutting edge by responding to consumer demands in this new virtual-aware world. Due to the positive responses from the participants, future plans are to integrate additional garment styles and increase participation. While 3D body scanning creates virtual body doubles that can bring many improvements for fitting to current methods, it does not introduce new concepts that depart from traditional fit practices. Yet, it is potentially a powerful tool for industry and would significantly save time and money.

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