Cross-Platform 3D Workflow for Developing Asymmetric Dress Forms for Wheelchair Users

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https://doi.org/10.15221/25.13

Abstract

This study investigates the development of a custom dress form for wheelchair users employing various 3D body scanning and 3D modeling technologies. Four wheelchair users are recruited. Depending on the participants' conditions, two different methods were used to acquire 3D body data: 3D body scanning and designing custom avatars. Both methods provided accurate data of participants' bodies with some drawbacks in using 3D body data from custom avatars, such as limitations on creating asymmetrical body shapes and the drooping belly between thighs when an avatar is in the seated pose for participant who has big bellies. While working on different applications, scaling issues were found to be problematic as the data was opened in the incorrect scale. The implementation of this 3D workflow has demonstrated the possibility of a customized dress form for wheelchair users. The dress forms were tested by young designers as a tool to help understand body shapes and sizes that are different from "standard models" and to help facilitate the pattern development process as well as fitting. The feedback was positive. The young designers found the dress form beneficial and helped them be less intimidated in designing and constructing garments for real people who have different sizes and body shapes.

Keywords: 3D body scanning, Custom dress forms, Inclusive fashion, Wheelchair users

1. Introduction

A dress form is a three-dimensional replica of the human body used in fashion design and garment construction to create, fit, and alter clothing without requiring a live model. Conventional dress forms are designed for mass market consumers using standard body measurements with symmetrical bodies. This approach often fails to accommodate individuals with real-size beauty or with disabilities, particularly wheelchair users. Young designers or students are often encouraged to think critically about inclusivity in their designs, yet they may lack direct experience with the unique needs of diverse body types and the unavailability of "real-size" dress forms.

Wheelchair users and individuals with conditions such as scoliosis, cerebral palsy, or muscular dystrophy present notable deviations from standard body proportions, necessitating custom-fitting approaches [1]. The conventional clothing in the mainstream market lacks designs that accommodate seated posture, requiring garments tailored to eliminate tightness and excess fabric while incorporating features like open waistlines and flexible structures for easier wear. Many wheelchair users opt for garments with stretch materials.

Research focused on using 3D body scans to create innovative body forms, including a woman's half-scale dress form in standing pose [2-4] and in active poses like cycling [5] and sitting poses [6]. Research highlights that incorporating posture-specific metrics into adaptive clothing design is essential for functional comfort, including reducing pressure points, accommodating seated postures, and facilitating ease of dressing [7]-[8].

Advances in 3D body scanning and modeling technology allow designers to capture precise postural and asymmetrical features, creating customized dress forms and digital prototypes that more accurately represent diverse body shapes [2],[9]-[10].

The gap in fashion education regarding accurate representation of diverse body types poses challenges for young designers, particularly in patternmaking courses [10]. Without appropriate dress forms, young designers struggle to create well-fitted garments for individuals with disabilities. Previous studies had developed different types of foam dress forms or 3D print forms using 3D scanning technologies [4],[10] and using 3D modeling software to create a customized avatar [11].

This exploratory study aims to explore a workflow that uses advanced 3D technologies to develop full-scale, custom foam dress forms for wheelchair users. In turn, assisting young fashion design students in conceptualizing and constructing garments for non-standard body types. By integrating these technological advancements, the project aspires to cultivate a new generation of designers capable of producing inclusive and functional fashion for all members of society.

2. Method

For the study, four wheelchair users were recruited to provide insights into their specific fitting needs. The conditions of the four participants are: model 1 can stand and walk for a short time if needed to, but mainly relies on a wheelchair, model 2 has paraplegia but is independent and can take care of herself, and models 3 and 4 can move both arms a little bit and have 24-hour care to help them with everyday chores. The participants were informed that they would each be a model for students in the introductory flat pattern class's projects, and they would also participate in the design process for creating custom dress forms.

The original plan was to 3D scan all four participants using the Vitus Smart XXL 3D Body Scanner, then perform 1-inch cross-section slices to create a foam dress form. After reevaluating the 3D body scan chamber capacity and the participants' conditions, several limitations were encountered. First, the chamber's door was not wide enough to accommodate a wheelchair, limiting access for some participants. Second, to get on top of the scanning platform, there are steps that some participants could not navigate independently. Third, the scanning process required the participants to maintain specific postures, whether in a standing or seated position, which were challenging for individuals with limited mobility and for those who could not hold their upper bodies without any back support. To address these challenges, the original plan was adjusted to ensure the participants' safety and the accuracy of the scan images. Only model 1 can get into the chamber and be scanned independently without any assistance. Model 2 was able to be scanned with assistance. Since model 2 had no other health concerns, she could not stand or sit without any support. Three people carried her into the chamber and set her onto the bench, then held her in place during the scan. The seated position was scanned. Figures 1-2 show 3D scanned images of models 1 and 2.

Fig. 1. 3D Scanned Image of Model 1

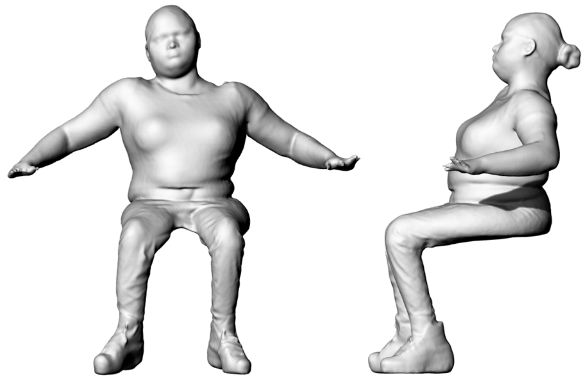

Fig. 2. 3D Scanned Image of Model 2

Models 3 and 4 were not scanned due to their mobility and health restrictions; therefore, alternative methods to acquire 3D body images were used. To capture their body shapes and measurements accurately, a combination of manual measurements and 3D modeling techniques was employed. First, the body measurements, including different circumferences and lengths, were manually taken using a measuring tape while the participants were in a seated position. Additional measurements from traditional standard body measurement points were taken to ensure body data accuracy, for example, upper and lower chest circumferences, waist-to-hip depths of front and back, waist-to-hip-to-back of knee length, center front length to top of thigh, center back length to the top of the seat, ranges of arm movement to possible pocket placement, etc. Since the participants had unique body sizes, the images of the nearest-sized avatars in seated pose in front, back, and side views were created and marked to assist designers in visualizing where to measure. Then, the measurements were input to Clo3D to create customized avatars of the models (see figures 3-4). The avatar files were then exported to OBJ files.

Fig. 3. Custom Avatar of Model 3

Fig. 4. Custom Avatar of Model 4

After the avatar files were created and modified to ensure an accurate representation of each participant's body measurements, Anthroscan was employed to create 1-inch cross-sectional slices from under the chin down. These steps followed previous studies (Ling et al., 2023; Phoenix & Ashdown, 2018), except that the present study used 1-inch slices to build a full-scale dress form instead of 1/4- or 1/2- inch slices to make half-scale forms. The rationale for developing full-scale dress forms was twofold. First, they provide a more accurate representation of individuals with irregular body shapes, which allows young designers to better visualize the figures of their models as well as to develop designs and patterns, particularly during 2D pattern development. Second, full-scale forms are essential for fitting sessions, as they more closely replicate the actual model's proportions and enable more precise assessment of muslin fittings and garment fit. In each cross-section slice image, two reference measurements of height and width were marked to ensure accurate scaling of the dress forms and screen capture to save the image. The overall cross-section was saved for reference for front, back, and both side views, and later labeled the slices in order from top down. Adobe Illustrator was used to scale the image to make sure that the cross-section image has the correct measurements. This step is time-consuming as there is a minimum of 30 images for each participant. Figure 5 summarizes the steps of the workflow.

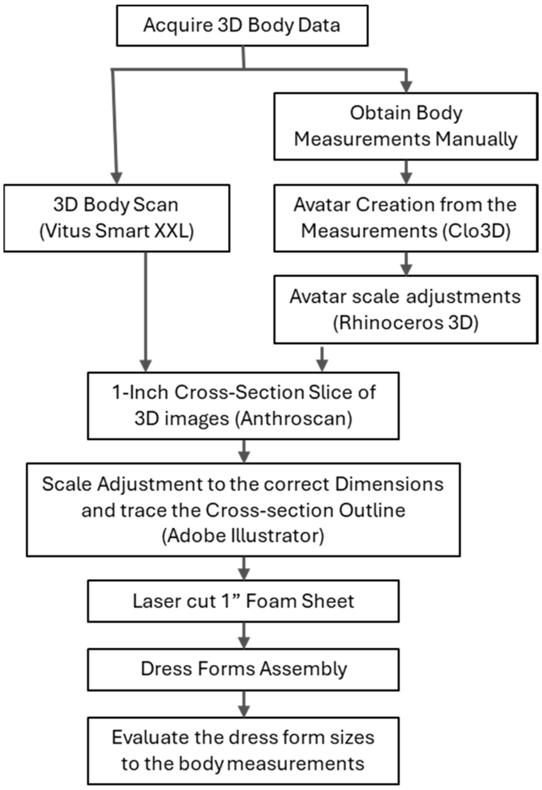

Fig.5. Summary of the Workflow

To assemble the dress forms, one-inch Polyethylene foam sheets were laser cut and glued to the dress forms. The last steps were to make sure that the foam dress forms' measurements are accurate and reflective of the participants' body shapes, and reference landmarks critical for pattern development were added to the dress form. For example, bust points, center front and center back lines, necklines, waistlines, and hip levels to help guide students in creating well-fitted patterns.

Two poses were selected to create the dress forms: one representing a seated position (models 2 and 3) and the other a standing position (models 1 and 4). Diverse postures were chosen for each model based on their anatomical configuration and daily activities. For instance, although Model 4 remains in a wheelchair throughout the day, she engages in a stretching regimen daily that necessitates standing for a specified duration. Model 3 is restricted to the use of a wheelchair; consequently, a seating arrangement is more necessary than an upright posture. In the end, the dress forms were built from below the chin to four inches below the crotch. Figure 6 shows the final custom foam dress forms of all four participants.

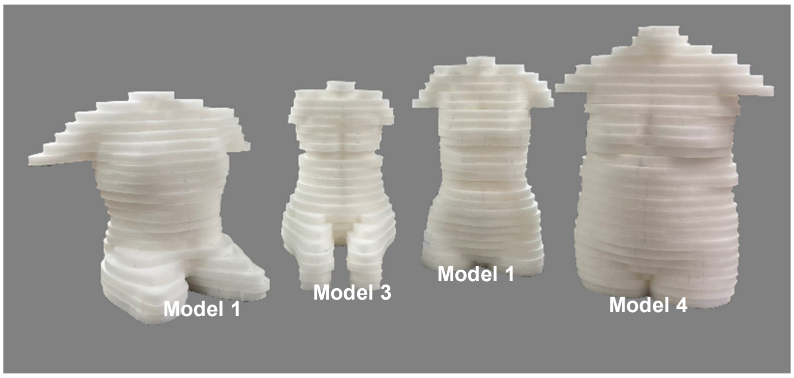

Fig. 6. Finished foam dress forms

3. Results and Discussion

3.1 Comparison of the 3D body scan data and the customized avatar data

The data obtained from a 3D body scanner is more accurate than the customized avatar data, as the scanning process captures precise measurements directly from the participants' bodies. However, if the model cannot hold the required posture by him-/herself during scanning, the accuracy can be inaccurate in some areas. For example, in this study, model 2 had three people hold her stable during the scan process; extra hands that were on the model's body could interfere with the accuracy, and the pose that the model held during the scan might not be as natural as when they are sitting in a wheelchair, as seen in Figure 7.

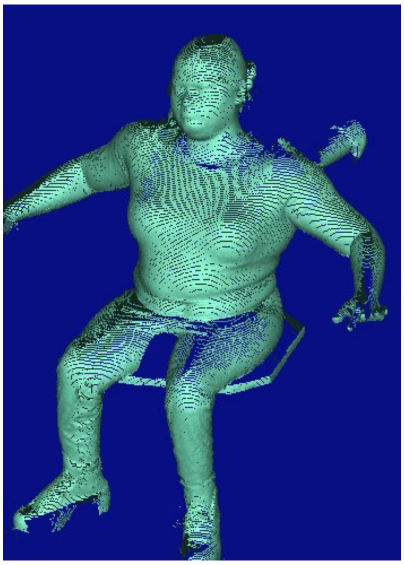

Fig. 7. Model 2 scanned image with the extra hands of the assistants

The ability to customize avatars provides an alternative method when 3D body scanning is not feasible. In this study, the application used for avatar creation only allows the creation of symmetrical body shapes, which may limit the representation of the unique asymmetries found in individuals with disabilities. There is limited body measurement information that can be input to the program, which may not fully capture the complexities of their body shapes. This highlights the necessity for ongoing advancements in 3D scanning technology and modeling software to accommodate better the diverse needs of individuals with disabilities in fashion design. Future work should focus on enhancing avatar creation tools to represent diverse body types and asymmetries better, ensuring more inclusive garment design.

3.2 Comparison of the standing pose and the seated pose

In comparing the standing and seated poses, it is evident that the seated position is crucial for accurately addressing the fitting needs of wheelchair users, as it reflects their everyday posture and the fit of the patterns. While the 3D body scan captured the correct measurements and shapes, the bottom of the model was not translated correctly, as it shows a very flat surface, which does not represent the natural contours of a seated body.

This study found that the custom avatar depicted a more realistic representation of the seated posture in terms of the bottom surface. However, if the model has large waist measurements or a belly, when changing the pose from standing to sitting, the computer algorithm will pull part of the belly in between the legs, squeezing part of the belly to be pulled and hung between the legs, as shown in Figure 3, side view. The circumferences of the high waist, diagonal circumference over the waist-to-hips, and thighs might not be as accurate as the actual body measurements. This may be due to the seated pose; the human body tends to redistribute weight differently compared to standing. Depending on the model's muscle-to-fat ratio, the computer algorithm may not accurately represent the real human body. Realistically, the belly may drop down more over the thighs, and the hips may expand onto the seat more than presented on the avatar. Consequently, addressing these discrepancies is essential for improving the accuracy of digital representations and ensuring that the resulting garments fit comfortably for the models.

3.3 Technical challenges and limitations

This study employed different 3D scanning and 3D modeling technologies, such as Vitus Smart XXL 3D Body Scanner, Anthroscan, Clo3D, Rhinoceros 3D, and Adobe Illustrator. While there is no issue viewing the scanned data on Anthroscan, obtaining cross-section slicing images takes several steps. First, the measurements are marked on each of the cross-section images and screen captured. Then, Adobe Illustrator was used to trace the outline and scale it to the correct measurements. These steps are time-consuming and require careful attention to detail to ensure accuracy. Additionally, the integration of various software tools presents challenges in maintaining consistency across the design process.

Once the custom avatar is created, the data file is sent to get the 1-inch cross-section slices. After opening in Anthroscan and Rhinoceros 3D, the avatar files were not opened in the correct scale. The 3d figures were only 3 mm tall. These caused much confusion as we tried different settings on all three programs, but the problems still persisted. In the end, to troubleshoot the scaling issues, we had to perform manual adjustments, which delayed the overall workflow and required additional validation to ensure accurate representations of the participants' body shapes and sizes. These challenges underscore the necessity for improved interoperability between different 3D modeling software and scanning technologies, which can streamline the workflow and enhance accuracy in fashion design for individuals with disabilities.

3.4 Perceptions and applications of the custom dress form

Overall, the comparisons of the participants and dress forms are accurate. The participants were surprised and happy to see themselves in the custom dress forms and the avatars. The young designers found the dress forms to be very beneficial in the design process, pattern construction, and fitting. As some of them never met the participants before, only interviewed them virtually or on the phone, the dress forms help visualize the body shape and size, along with designing an appropriate design that complements the model's body and enhances the comfort and function of the garment to fit the model's needs. In the pattern construction phase, the first and second draft patterns were quickly draped on the dress form and modified to fit the body before creating the fitting muslin. The fitting muslin was tried on the dress form, marked, and adjusted. These steps are crucial not only for the designers but for the models as well. At least two adjustments of the muslin fitting with the dress form were done before a real fitting session with the models. In the end, only one fitting session was needed with the model before final pattern adjustments. Some of the patterns did not need to make any adjustments. The feedback from young designers is very positive, and some of them mentioned that this project is fun, it is great to work with a real client who is different from the usual size, and they would like to design for people with disability again. The participants (models) were also pleased that they did not have to come several times for the fitting, and being able to see their custom dress form was a great experience.**2.2.**

4. Conclusion

This study illustrates a feasible cross-platform workflow for generating custom asymmetric dress forms using commercially available 3D technologies, despite existing software constraints on asymmetry handling and avatar parameterization. The interdisciplinary collaboration combined the expertise of different areas of study, demonstrating the importance of partnerships in inclusive design. This collaborative approach not only enhances the educational experience for fashion design students but also fosters a deeper understanding of the diverse needs of individuals with disabilities in the fashion industry. Future research directions include exploring more flexible body scanning modalities, refining avatar creation pipelines for improved accuracy, and developing more efficient methods for generating sliced images and constructing dress forms.

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