# Development of a Web Application for 3D Body-Garment Fit Analysis

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https://doi.org/10.15221/24.39

## Abstract

The fashion industry has long struggled to achieve the ideal fit for clothing because of the wide range of body types and customer preferences for fit. With the creation of a web application that allows for the objective assessment and quantification of the body-garment interaction using 3D scanned models, this research project presents a novel methodology.

The application leverages 3D scanned models to provide cross-sectional visualization and measurements at key areas. This application addresses the limitation of 3D scans being used to capture only the outer surface of the clothing, making it difficult to quantify the distance between the inner fabric surface and the body. This research project aims to address this issue of fit analysis through objective evaluation and quantification of the body-garment relationship using 3D scans.

The application's features include landmark-based distance computations, visual references, and ease value calculation reports, addressing the difficulty faced by fit technicians in comparing the body and the garment. This data-driven approach empowers fit technicians to make informed decisions, leading to improved garment fit, reduced returns, and enhanced customer satisfaction.

The research methodology employs an experimental design, focusing on the development of a web application with iterative refinement of its algorithms and functionalities through testing. The research findings and the development of this comprehensive 3D body-garment measurement web application contribute to the advancement of fit analysis in the apparel industry.

**Keywords**: 3D Fit Analysis, Web application, Body-garment relationship, Cross-sectional measurements, Ease quantification

## 1. Introduction

The apparel industry is constantly seeking innovative solutions to enhance garment fit and improve customer satisfaction. Traditional methods of garment fit analysis, such as visual assessments and manual measurements, can be time-consuming, subjective, and prone to errors. With the advent of three-dimensional (3D) body scanning technology, a new era of possibilities has emerged in the realm of garment fit analysis.

3D body scanning offers a rapid and accurate means of capturing detailed body measurements, enabling the creation of realistic virtual representations of human forms. This technology has gained significant traction in recent years, with companies like Victoria's Secret and Jockey International adopting 3D body scans to refine their size systems and enhance product development.

This paper delves into the applications of 3D body scanning for garment fit analysis, exploring its potential to revolutionize the way garments are designed, manufactured, and fitted.

The fashion industry is always changing due to shifting consumer demands and technological advancements. Finding the ideal fit for clothing is still a challenge in this ever-changing world of fashion. This problem results from the wide range of customer body types and sizes as well as the arbitrary nature of fit preferences. What fits well on one person may not fit the same on another.

With the advent of 3D body scanning technology, body measurement methods have undergone a paradigm shift that has improved mass production, customization, and fit of clothing. One of the key applications of 3D body scanning technology in the apparel industry is garment fit analysis. The precise evaluation of clothing fit, virtual fitting sessions, and the detection of possible fit problems are all made possible by this technology. In addition to producing garments of superior quality and accuracy, the implementation of 3D scanning technology can substantially decrease the time and expense associated with their development.

Fit assessment employs various methods like visual assessment by fit technicians, manual measurements with tape measures, and garment fit testing on fit models or mannequins. Currently, methods for evaluating garment fit that rely on subjective evaluation or visual assessment are not always accurate or consistent. For this reason, it is necessary to use more precise and objective metrics to quantify the fit assessment techniques. Although the term "fit" can refer to both an objective and a subjective assessment of a garment, meeting their requirements for a "good fit" is not possible without a set of precise measurements.

The development of a tool is critical. The limitations of conventional garment fit assessment techniques, which rely on subjective, human error-prone linear measurement. The purpose of the research is to develop a standardized, quantifiable instrument for assessing garment fit. The availability of comprehensive fit analysis data enables fit technicians to make well-informed decisions during the initial phase of product development. It will also help to reduce returns as well as samples, leading to cost savings for both consumers and manufacturers.

### 1.1. Anthropometry in apparel design

The examination of body measurements plays a crucial role in the field of apparel product development. Anthropometry, as one of the earliest techniques employed to evaluate human body size and shape, holds significant importance [1]. Various anthropometric tools have been utilized for centuries to assess bodily dimensions in clothing construction, including calipers, weight balances/scales, tape measures, and calibrated rulers [2].

### 1.2. Anthropometric landmarks

Some traditional apparel landmarks are identified by palpitating for skeletal protrusions that cannot be located from the surface data of the body, so software developers for automated measurements generate a method of finding an equivalent landmark based on the surface geometry of the body [3,4].

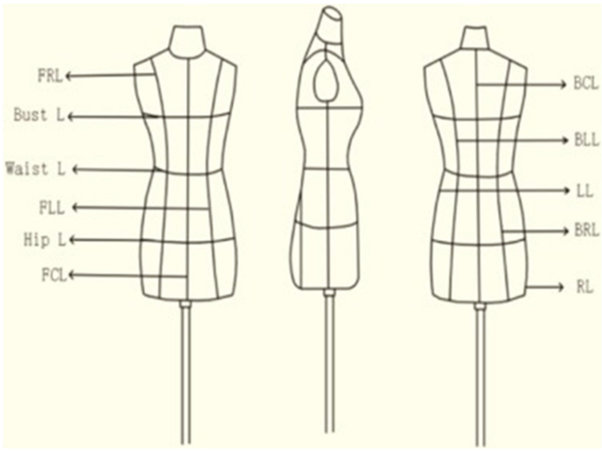



*Fig. 1. Features lines of a dress form [5].*

### 1.3. Apparel fitting

Methods of analyzing or quantifying fit generally involve subjective assessment, by the wearer or by an expert, in fit or wear tests. Fit studies in the past have been challenging to conduct and have yielded inconclusive results. The human body has great variations in terms of size, shape, and posture which makes the situation more difficult to handle, along with concerns about personal fit preferences and the range of clothing styles and purposes that must be taken into consideration. The interaction between the body and the garment can only be inferred from the form of the garment, making understanding fit a three-dimensional problem [6].

### 1.4. Fit evaluation

Analysis of the fit of clothing is a complex process in which the relationship between the human body and clothing is assessed to judge how well the clothing conforms to a set of requirements [7]. Fit testing is an important part in which every apparel company must engage to create well-fitting clothing [8]. The development of consistent fit testing methodologies for both industry and apparel research is critical to developing clothing with better standards of fit [9]. Although there are several protocols to follow when assessing the fit of clothing, there is currently no standard protocol to assess the quality of fit for apparel in general [10].

### 1.5. 3D body scanning for apparel industry

Three-dimensional scans can be used for fit analysis through recent technological advances in 3D body scanning. Currently, body scanners are used within the apparel industry to improve apparel fit and customer satisfaction in the retail and product development sectors. With this technology, companies are capable of rapidly capturing dozens of their customers' body dimensions like circumference, length, and volume. The 3D garments acquired by 3D scanning are a true representation of how a garment appears on a real person wearing a real physical prototype. With the scans, it is very easy to see the drapability and fit of the garment [11].

### 1.6. 3D fit testing

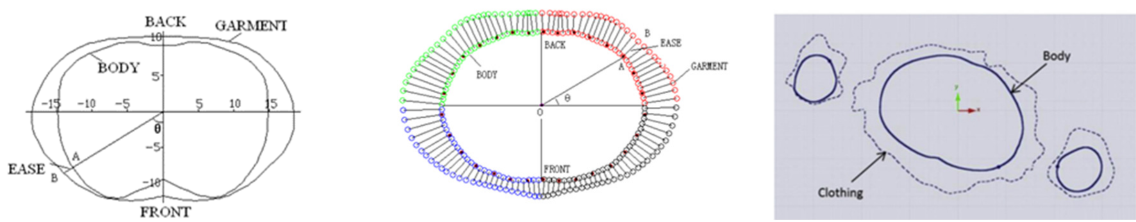
Body scanning technology enables us to digitally capture the human body's three-dimensional surface area when it is dressed in its most basic clothes for body measurements or when it is in clothing prototypes for fit evaluation. Analyzing and classifying the fit of ready-to-wear on the entire spectrum of body types found in the target market is probably made easier by comparing a 3-D scan of the fully clothed figure with a scan of the same subject wearing minimal clothing [12].

### 1.7. Analysis of body garment relationship

In a study, Kathleen Robinette suggested combining 3D scans of the naked and clothed bodies to look into the area in between [13]. This is the essence of clothing fit, expressed in a quantifiable and objective manner. Clothing fit can be further assessed with more quantitative measurements such as linear dimension, cross-sectional slice area, and space volume between the body and clothes. However, due to the complicated geometry of the human body, the total variation between the body and clothes is difficult to measure [14].

#### *1.7.1. Cross-sectional ease evaluation methods*

It can be radial distance, normal distance, or minimum distance calculation. Radial Ease calculation, the radial distance between the body surface and the clothing surface measured from the same center [15]. Normal distance is the shortest distance between the body and the garment, and it is the normal offset value in a 3D virtual garment [16]. Lu et al., 2014 in their study calculated distances between the body scan and the clothed scan to analyze fit, in the context of the minim distance calculation method, it has an approach focusing on determining the shortest distance between the body scan and the clothed scan to assess fit along with other parameters like minimum, maximum and average distances.




a b c

*Fig. 2. a) Radial distance, b. normal distance; c. Minimum distance [16,17]*

## 2. Tools used for 3D scan evaluation

The 3d Measure Up which is a web application by Prototech Solution has the feature for accurately predicting anthropometric measurements from 3D human scans. This feature is based on a model-based approach that integrates information from multiple poses to optimize surface-based shape features for predicting standard anthropometric measurements[18]

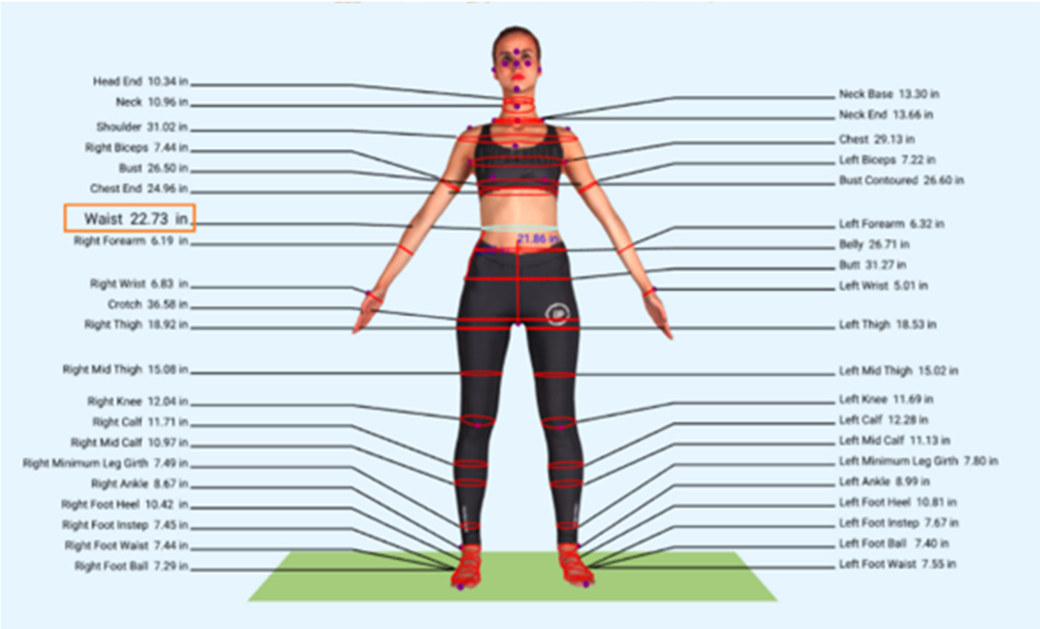



*Fig. 3. Automatic landmark detection and measurement extraction feature [18].*

## 3. Research methodology

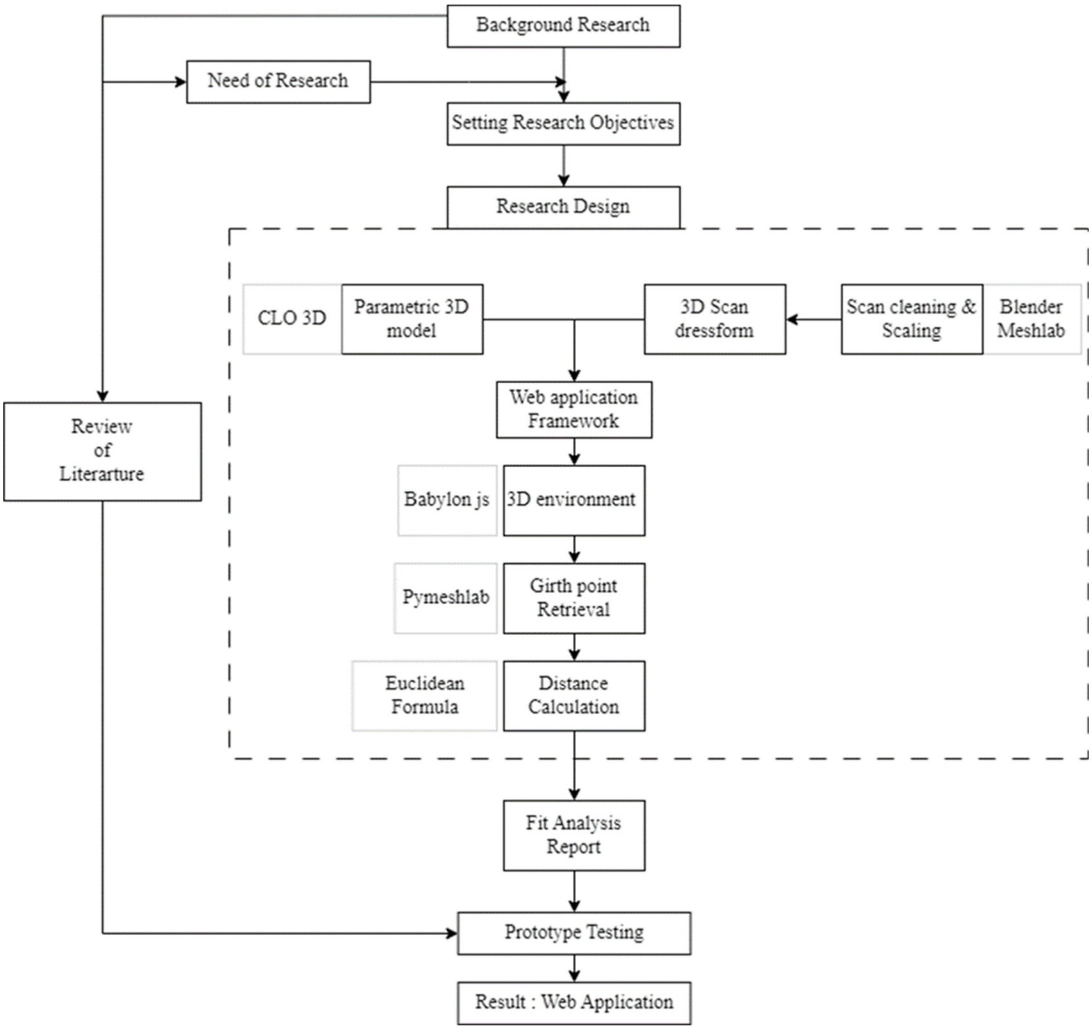



*Fig. 4. Research Methodology for application development*

## 4. Application development

The development of a comprehensive web application for 3D body garment fit analysis involved testing and validation to ensure its effectiveness in functional to evaluate the relationship between the human body and clothing so as to make sure that this can be utilised seamlessly in the apparel industry.

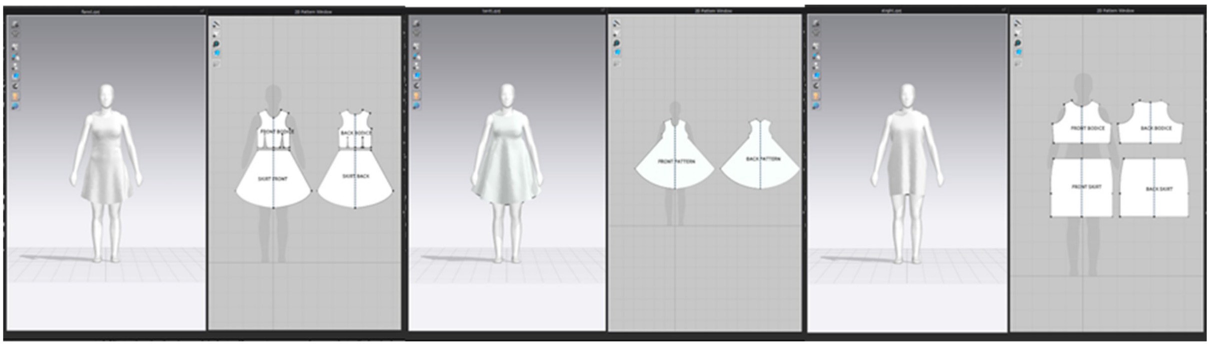


*Fig. 5. Different styles of dress developed for parametric models*
*1.A-line dress, 2. Tent dress, 3. Straight dress without darts*

Clo 3D software was useful for the creation of various dress types by pattern making and stimulating them onto the model. This enabled easy testing and evaluation of a wide range of dress styles and silhouettes. The testing garments included different dress types like sheath dresses, straight dresses, tent dresses, and so on to ensure accurate and reliable fit analysis capabilities across different categories, styles, and silhouettes.

### 4.1. Application features

3D model visualisation : Users can upload 3D models of both unclothed and clothed to view them side by side or for overlapped view. This helps for visual inspection and comparison of models side to side.

*4.1.1. Manual slicing:*
User can manually slice the pattern with the mouse by moving the plane manually to the required section of the model.

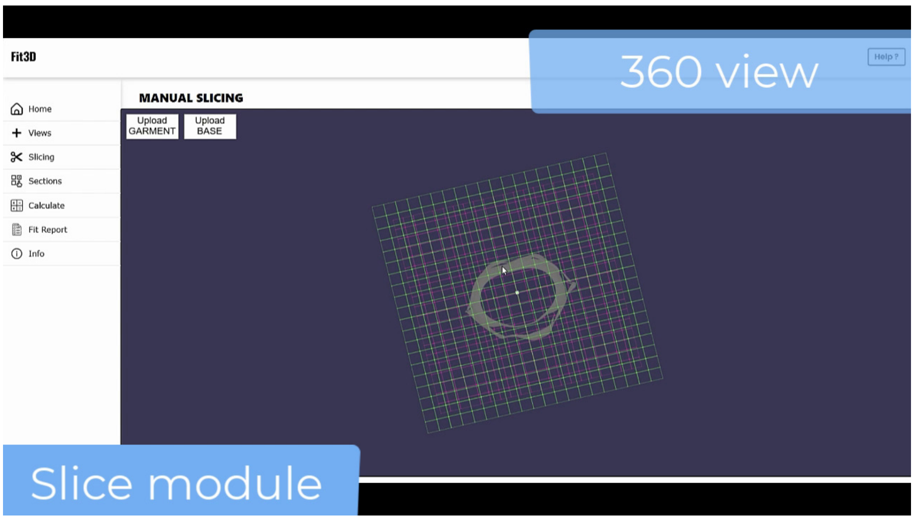



*Fig. 6. Slice Module*

*4.1.2. Cross sections:*
In this section, users can view the cross sections of models uploaded at its bust, waist, and hip.

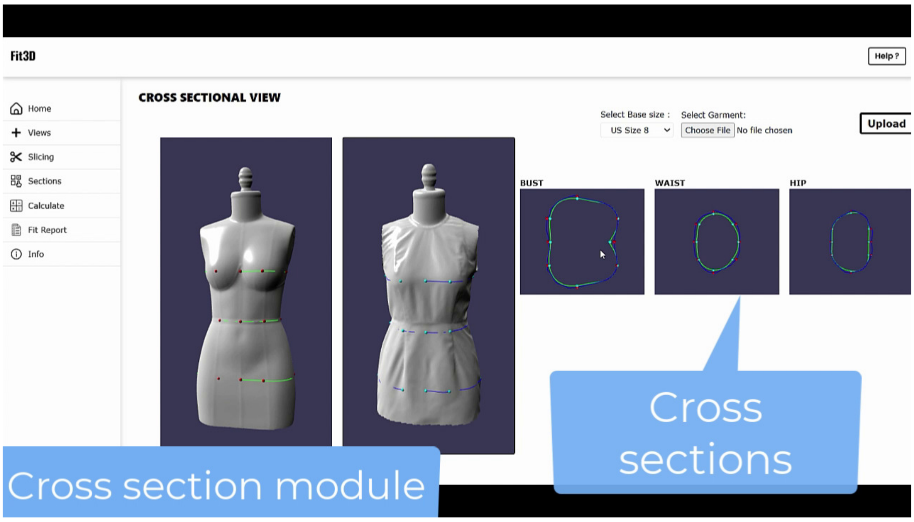



*Fig. 7. Cross section Module*

*4.1.3. Distance calculation:*

This section displays the landmark based distance calculation between the body and the garment. The landmarks or Point of Measures (POM) are named as CF-Center Front, PS FR- Princess Seam Front Right, SSR- Side Seam Right, PS BR- Princess Seam Back Right, CB-Center Back, PS BR- Princess Seam Back Left, SSL- Side Seam Left, PS FL- Princess Seam Front Left.

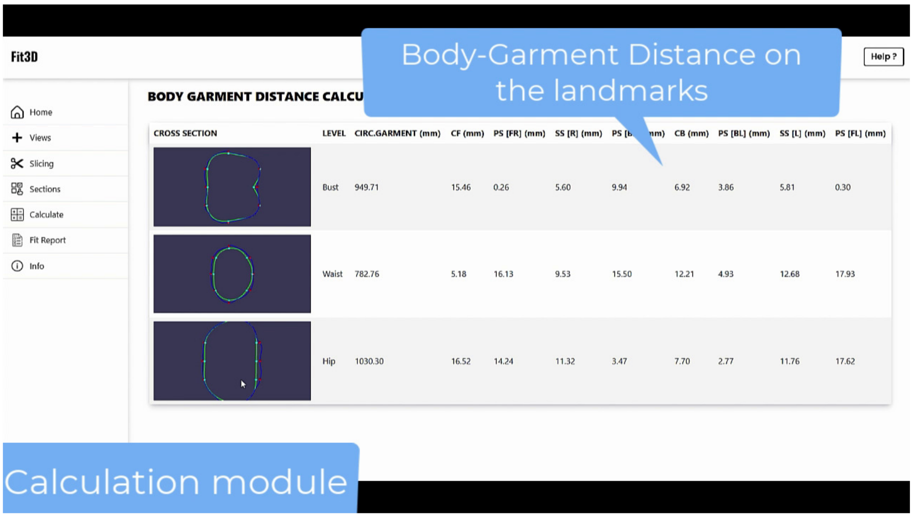



*Fig. 8. Distance calculations*

*4.1.4. Fit analysis report :*

This page provides a calculated report that comprises level, landmark, required measurement, tolerance, actual measurement, difference, and pass/fail status. Users can view individual measurements, their status and the table can be downloaded.

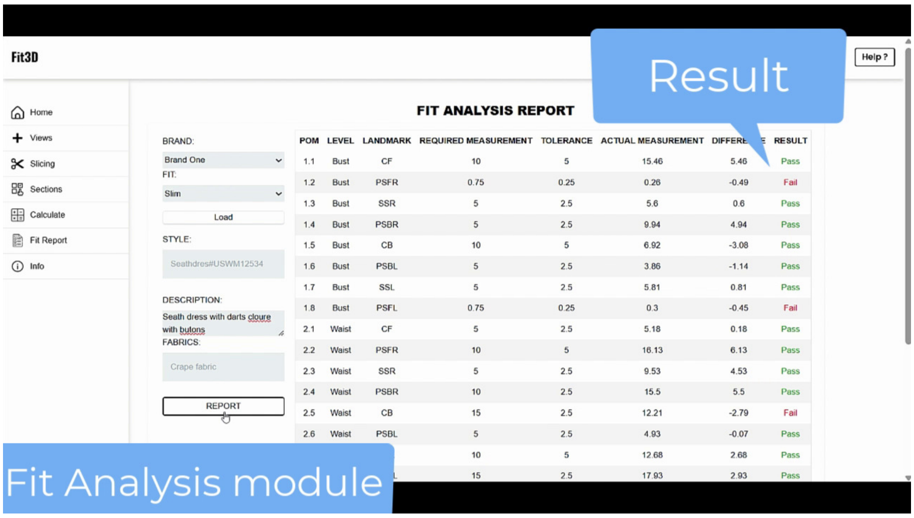



*Fig. 9. Fit analysis report*

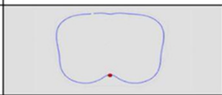
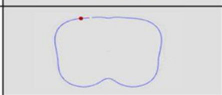
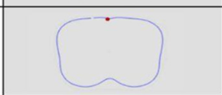
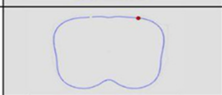
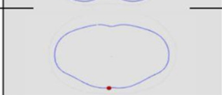
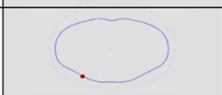
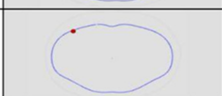
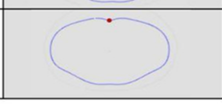
| PoM | LEVEL | LANDMARK | IMAGES | DESCRIPTION |
|---|---|---|---|---|
| 1.1 | Bust | CF |  | Center Front at Bust |
| 1.2 | Bust | PSFR |  | Princess Seam Front Right at Bust level |
| 1.3 | Bust | SSR |  | Sideseam Right at Bust |
| 1.4 | Bust | PSBR |  | Princess Seam Back Right at Bust level |
| 1.5 | Bust | CB |  | CenterBack at Bust |
| 1.6 | Bust | PSBL |  | Princess Seam Back Left at Bust level |
| 1.7 | Bust | SSL |  | Sideseam Left at Bust |
| 1.8 | Bust | PSFL |  | Princess Seam Front Left at Bust level |
| 2.1 | Waist | CF |  | Center Front at Waist |
| 2.2 | Waist | PSFR |  | Princess Seam Front Right at Waist level |
| 2.3 | Waist | SSR |  | Sideseam Right at Waist |
| 2.4 | Waist | PSBR |  | Princess Seam Back Right at Waist level |
| 2.5 | Waist | CB |  | Center Back at Waist |

*Fig.10. Point of Measurement*

*4.1.5. Cross-sectional analysis*

Cross-sectional analysis is based on an auto-slicing feature at different levels of the body, which are the bust, waist, and hip. The web application generates cross-sectional views of the 3D models with key landmark points at each level. This feature provides a visual representation of the relationship between the body and the garment at these critical fit locations. By analysing the cross-sections, users can identify areas of potential fit issues, such as excess fabric, tightness, or misalignment, and make informed decisions about necessary adjustments.

The cross-section analysis feature is developed using a combination of Pymeshlab which is the Python library of meshlab and Matplotlib, a popular data visualisation library. The 3D model is sliced at different levels with Pymeshlab and 3d point at each levels are formatted and retrieved into a JSON file which is displayed in the web application. Matplotlib is then used to allocate the eight landmark based points on each level and to generate visual representation graphs of the cross-sections. This will be helpful to identify potential fit issues, such as excess fabric, tightness and so on.

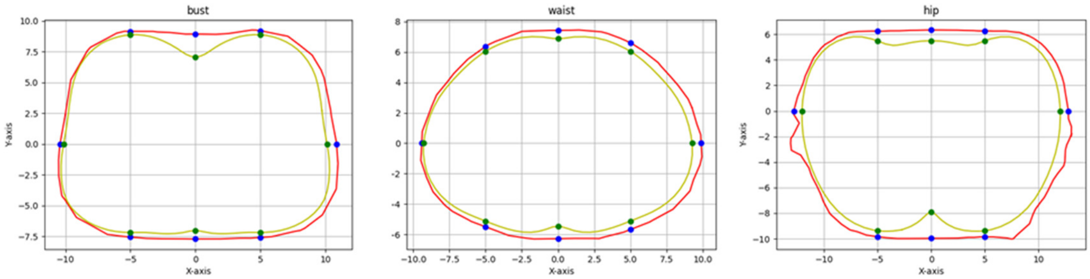



*Fig. 11. Cross-sectional plotting at Bust, waist, hip*

*4.1.6. Distance calculation*

The web application calculates the landmark-based distance between the body and the garment using predefined landmarks like center front, princess seam, side seam, and center back. This quantitative analysis of the fit allows users to assess the degree of ease and the overall relationship between the body and the garment. The distance measurements at each landmark are displayed, enabling users to identify areas where the garment may be too tight, too loose, or not conforming to the body's shape. The distance calculation feature is based on retrieving the 3D coordinates (x,y,z) from each of the eight points of the body or base model and corresponding points on garments. The distance is then calculated based on the Euclidean distance formula which represents the shortest distance between two points.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

*4.1.7. Fit analysis report*

The web application generates a comprehensive fit analysis report that includes the level, landmark, required measurement, tolerance, actual measurement, difference, and pass/fail status. This report provides a detailed overview of the fit assessment, allowing users to view the individual measurement details and identify areas where the garment may not meet the desired fit criteria. The ability to download the report enables users to share it within the apparel industry with other stakeholders, such as designers, pattern makers, and manufacturers, facilitating collaborative decision-making and improving the overall garment development process.

## 5. Limitations

A cross-sectional study has been conducted only based on female body type and for only a single category of apparel at prespecified three levels: bust, waist, and hip.

- Multi-layered garments present a challenge in obtaining accurate cross-section points due to the complexity of the garment structure; only the outer layer would be obtained from the scan.
- Dresses with intricate cutouts at the specified level will pose a difficulty in plotting cross sectional points, especially at the areas where the fabric is intentionally removed, which might be identified as the endpoint of the girth.
- The body scan and garment scan should have the same preprocessing aspects like scaling, axis placement; otherwise, the result might have variation.
- The scans used for the application should be simplified scans that are of minimum file size so that it can be easily loaded into the application.

## 6. Future scope

Application could be developed further to involve a wider set of base models based on their size ranges.

- Further development of this application for enhancing fit analysis is possible by using machine learning and AI techniques.
- There are different possibilities to explore other areas of measurements where fit issues are likely to occur like the armhole.
- Integrating real-time body scanning technologies with personalized fit assessments can expand its application to retail stores.
- The study was currently conducted with a dress category only for females; incorporating a broader range of garment types and styles can be done in later stages.
- Ensuring more compatible and accessible design by optimising the application and its functions.
- With further development automatic pattern generating systems can be developed with the help of landmark locations.

## 7. Conclusion

The development of a comprehensive web application for 3D body garment fit analysis represents a significant advancement in the apparel industry's pursuit of optimized garment fit and enhanced customer satisfaction. By leveraging the power of parametric models and integrating cutting-edge technologies, this application has the potential to revolutionize the way designers, pattern makers, and fit technicians approach the garment development process. At the core of this application's success is the rigorous testing and validation process, which ensures the accuracy and reliability of the fit assessment capabilities. The use of parametric models, both for the human body and the garment, has been instrumental in this endeavor. These highly customizable and realistic virtual representations allow for precise control over a wide range of parameters, enabling a thorough evaluation of the garment-body relationship across diverse body types and dress styles.

Moreover, the web-based nature of the application and its accessibility to a wide range of users. This accessibility empowers more individuals and businesses to optimize garment fit and improve the overall customer experience. The web application's ability to facilitate communication and collaboration among industry stakeholders further strengthens its position as a valuable tool in the pursuit of improved garment fit and customer satisfaction. By enabling the seamless sharing of virtual fit assessments and fostering informed decision-making, the application can streamline the product development process and enhance the overall efficiency of the apparel industry.

In conclusion, the development of this comprehensive web application for 3D body garment fit analysis represents a significant milestone in the apparel industry's quest for optimized fit and enhanced customer satisfaction. By leveraging the power of parametric models, cutting-edge technologies, and a systematic testing approach, the application has the potential to revolutionize the way designers, pattern makers, and fit technicians approach the garment development process. As the project continues to evolve, addressing challenges and embracing future scopes, it will undoubtedly play a pivotal role in shaping the future of the fashion industry, empowering brands and manufacturers to deliver garments that truly fit and delight their customers.

## References


[1] S. B. Heymsfield, B. Bourgeois, B. K. Ng, M. J. Sommer, X. Li, and J. A. Shepherd, "Digital anthropometry: a critical review," Eur. J. Clin. Nutr., vol. 72, no. 5, pp. 680-687, 2018, doi: https://doi.org/10.1038/s41430-018-0145-7.

[2] S. B. Heymsfield and J. Stevens, "Anthropometry: continued refinements and new developments of an ancient method," Am. J. Clin. Nutr., vol. 105, no. 1, pp. 1-2, 2017, doi: https://doi.org/10.3945/ajcn.116.148346.

[3] M. A. Brunsman, H. A. M. Daanen, and K. M. Robinette, “Optimal postures and positioning for human body scanning,” presented at the International Conference on Recent Advances in 3-D Digital Imaging and Modeling, 1997, doi: https://doi.org/10.1109/IM.1997.603875.

[4] R. P. Pargas, N. J. Staples, and J. S. Davis, “Automatic measurement extraction for apparel from a three-dimensional body scan,” Opt. Lasers Eng., vol. 28, no. 2, pp. 157-172, 1997, doi: https://doi.org/10.1016/S0143-8166(97)00009-2.

[5] X. Tang, X. Pan, L. Liwen, and X. Qing, "Automatic human body feature extraction and personal size measurement," J. Vis. Lang. Comput., vol. 47, pp. 9-18, 2018, doi: https://doi.org/10.1016/j.jvlc.2018.05.002.

[6] H. K. Song and S. P. Ashdown, "An exploratory study of the validity of visual fit assessment from three-dimensional scans," Cloth. Text. Res. J., vol. 28, no. 4, pp. 263-278, 2010, doi: https://doi.org/10.1177/0887302X10376411.
[7] S. P. Ashdown, S. Loker, K. Schoenfelder, and L. Lyman-Clarke, "Using 3D scans for fit analysis," J. Text. Apparel Technol. Manag., vol. 4, no. 1, pp. 1-12, 2004.
[8] S. P. Ashdown and E. K. O'Connell, "Comparison of test protocols for judging the fit of mature women's apparel," Cloth. Text. Res. J., vol. 24, no. 2, pp. 137-146, 2006, doi: https://doi.org/10.1177/0887302X0602400207.
[9] E. Bye and K. LaBat, "An analysis of apparel industry fit sessions," J. Text. Apparel Technol. Manag., vol. 4, no. 3, pp. 1-5, 2005.
[10] H. K. Song, Y. Kim, and S. P. Ashdown, "Expert versus novice assessment of clothing fit; an exploratory study using eye tracking technology," Fashion Pract., vol. 13, no. 2, pp. 227-252, 2021, doi: https://doi.org/10.1080/17569370.2020.1781375.
[11] L. Bouvier, "Apparel Fit Evaluations of 3D Scans via Eye-Tracking," 2020.
[12] S. Ashdown, S. Loker, and E. Carnrite, "Digitizing the fit model using 3-D body scanning technology," presented at the VIII. International Foundation of Fashion Technology Institutes (IFFTI) International Conference, pp. 1-7, 2006.
[13] K. M. Robinette, "Fit testing as a helmet development tool," in Proc. Human Factors and Ergonomics Society Annual Meeting, vol. 37, no. 1, pp. 69-73, Los Angeles, CA, 1993, doi: https://doi.org/10.1177/154193129303700118.
[14] Y. L. Lin and M. J. J. Wang, "The development of a clothing fit evaluation system under virtual environment," Multimed. Tools Appl., vol. 75, pp. 7575-7587, 2016, doi: http://dx.doi.org/10.1007/s11042-015-2681-7.
[15] Z. Wang, R. Ng, E. Newton, and W. Zhang, "Modeling of cross-sectional shape for women's jacket design," Sen'i Gakkaishi, vol. 63, no. 4, pp. 87-86, 2007, doi: http://dx.doi.org/10.2115/fiber.63.87.
[16] J. Xu and W. Zhang, "The Vacant Distance Ease Relation between Body and Garment," in 2009 Second Int. Conf. Information and Computing Science, Manchester, England, UK: IEEE, 2009, pp. 38-41, doi: https://doi.org/10.1109/ICIC.2009.318.
[17] Y. Lu, G. Song, and J. Li, "A novel approach for fit analysis of thermal protective clothing using three-dimensional body scanning," Appl. Ergon., vol. 45, no. 6, pp. 1439-1446, Nov. 2014, https://doi.org/10.1016/j.apergo.2014.04.007.
[18] "3DMeasureUp - Body Measurement Software," 3DMeasureUp, 2024. [Online]. Available: https://3dmeasureup.ai/. [Accessed: 02-Oct-2024].