Comparative Analysis of Various 3D Scanners for Body-Garment Relationship Measurement

Chakravarthy PALANISAMY [1], Noopur ANAND [2], Manoj TIWARI [1],
Nafrin ASHKAR [1], Dhiya S. VARGHESE [1]
[1] National Institute of Fashion Technology, Kannur, India;
[2] National Institute of Fashion Technology, New Delhi, India

https://doi.org/10.15221/24.42

Abstract

This study aims to explore different 3D scanning technologies to scan both body and garment to check the fit in the ready-to-wear apparel industry. Even though 3D scanning technology is widely used to scan the body, scanning of garments remains underexplored.

The main objective of this research is to analyse different 3D scanners for body-garment analysis. This includes examining the scanned date for accuracy, reliability and body-garment scan alignment processes.

The study explores various scanning techniques like white light, infrared and photogrammetry for capturing body and gament details. Additionally, it examines various scanning techniques like scanning mode, resolution and other parameters to optimise the scanning process.

This study accesses the precision of the scanned model by validating the manual measurement taken using an anthropometer. Additionally, heat maps are created using 3D visualization software and compared.

In conclusion, this study aims to provide valuable insights into the selection and optimization of 3D scanning technologies to improve apparel fit. By addressing challenges and limitations associated with traditional measurement methods, the study seeks to enhance the accuracy and reliability of garment production processes. Leveraging innovative 3D scanning approaches, the research aims to improve customer satisfaction and drive technological advancements in producing optimally fitting garments.

Keywords: 3D scanner, Aligning, Accuracy &Reliability, Body-Garment relationship

1. Introduction

To revolutionize the apparel industry, the industry should address the problems related to establishing precise and accurate garment fit. The traditional practices always depend upon subjective assessments, resulting in inaccurate results. However, the capacity of the 3D scanners to revolutionize the apparel industry lies in their ability to produce more precise and accurate measurements. Although 3D scanners are widely used in many other industries, the usage of 3D scanners in the apparel industry is very limited. The objective of this research paper is to examine various 3D scanners available in the market to verify their accuracy and to determine the factors and parameters to get precise outcomes. This paper aims to address the problems related to conventional methods and investigate novel approaches using 3D scanning.

1.1. Three-dimensional body scanners

3D scanners are complex instruments that are used for examining various tangible objects in the environment. 3D scanning technologies were first developed in the 1960s using light, cameras and projectors. But these types of scanners were very time and labour consuming . These problems of traditional scanners were addressed with new technologies like white light, lasers, and shadowing methods by the 1980s [1]. The non-contact scanners significantly reduce inaccuracies commonly associated with conventional measurement techniques, offering accurate data for a wide range of applications [2].

Three-dimensional body scanning devices improve the precision and dependability of anthropometric measures by quickly recording angles, surface areas, and volumes, hence generating enduring records [3]. Cutting-edge 3D scanning technology enables the creation of very accurate digital body models, removing the need for human measurements and facilitating precise customization of clothing [4].

1.2. Classification of 3D Body Scanning Technologies

A large variety of 3D body scanners are available in the market today, with varying cost, accuracy, technologies, and other factors. Most of the commercial body scanners are immobile and have several light sources and sensors to collect data from different perspectives. There are mainly four types of technologies used in 3D body scanners : laser technology, white light technology, photogrammetry technology, and infrared technology [5].

1.2.1. Laser Scanning

In laser scanners, laser light is emitted onto the human body, and the image produced by the laser light is recorded by the sensors, which quantify the surface based on geometric concepts [4]. A triangular arrangement is formed between the laser dot, the camera and the laser emitter. This technology is referred to as the triangulation method. This triangulation method is used to identify the exact laser dot and to produce exact 3D data of the scanned item. This is done by calculating the laser dot distance by using the predetermined distance between the camera and the laser emitter and the angle of the emitter [6].

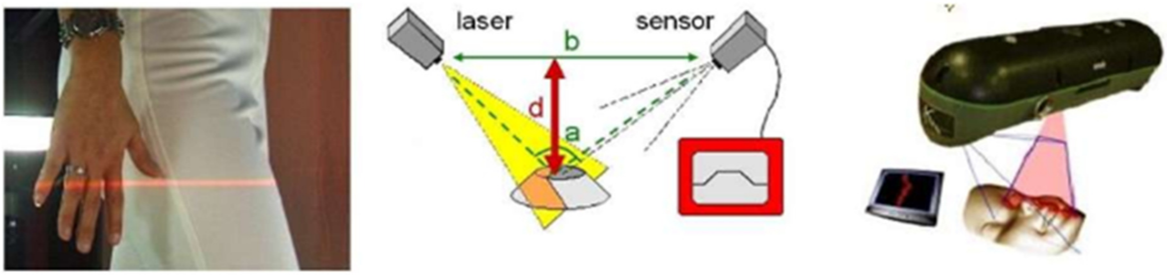


Fig. 1. Laser scanning technology.
Left: laser stripe on the human body. Center: triangulation method, different object heights result in different triangulation angles that can be measured by the light sensor. Right: the scanner unit is moved across the human body to scan its surface.[4]

1.2.2. Structured Light Scanning

Structured light scanning is a commonly used technology for measuring the human body by projecting precise light patterns, akin to the approach used in laser scanning [6]. During this procedure, body scanners that are fitted with structured light technology deploy white-light stripes onto the individual, which are subsequently recorded by cameras. The three-dimensional form of the body is ascertained by examining the curvature of these stripes over the surface of the specimen [8]. Structured-light 3D scanners have the capability to utilise either one-dimensional or two-dimensional patterns, such as lines or grids, which are projected onto the subject using an LCD light projector or sweeping laser. Positioned slightly off-center from the projector, the camera detects the distortion of the pattern and employs triangulation to determine the distance of each point on the line [1].

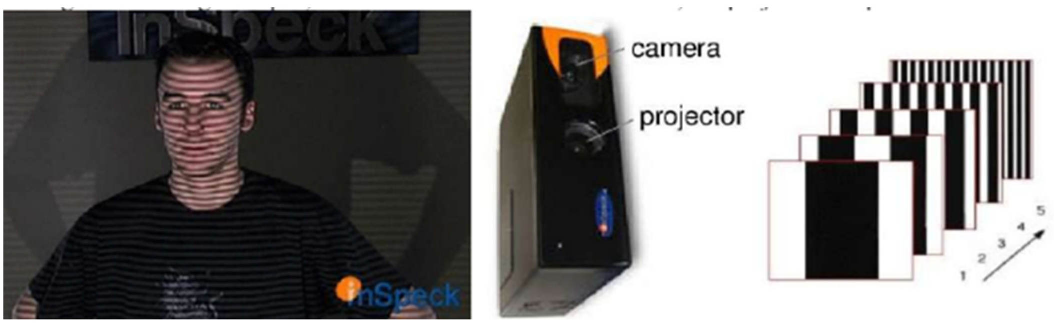
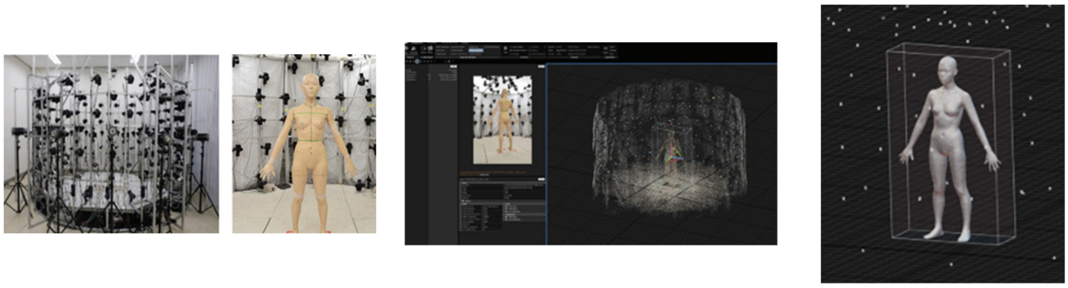


Fig. 2. Structured light scanning.
Left: projection of light pattern as stripes. Center: scanning device Capturor of InSpeck Inc. (Canada). Right: projected sequence of binary coded stripes pattern. [4]

An inherent benefit of structured-light 3D scanners is their rapidity, as they have the capability to concurrently record many points or the whole field of view, in contrast to techniques that measure one point at a time. By dramatically reducing or eliminating distortion produced by movement during the scanning process, this feature greatly improves the precision and dependability of the measurements [6].

1.2.3. Photogrammetry

Photogrammetry is a method that produces and analyses three-dimensional (3D) data from two-dimensional (2D) photographs instead of directly measuring the three dimensions. This application employs image processing and modelling methodologies to convert the human body into a digital format [4]. Typically, photogrammetric systems employ a single camera to record many photos under varying illumination conditions. Through the process of inverting the image generation paradigm, these systems are able to restore the orientation of the surface at every individual pixel. This is achieved by generating outlines from a sequence of images captured around a three-dimensional object, which is then projected against a contrasting background [1].



a b c

Fig. 3. Photogrammetry.
a) 143 pictures were taken b) Aligning images c) Mesh file generation

1.3. Methods for Evaluating the Quality of 3D Scans

Horstmann proposed a method to produce replicable 3D models by using different specimens. In this method, it allowed accurate assessment of changes in shape and form in biological morph types. Using this method, heat maps are produced in the translocation sites of produced morph types , enabling the identification of minute morphological characteristics and fluctuations. Heat mapping analysis can be used to improve apparel product fitting, thereby increasing precision and accuracy in clothing manufacturing [8].

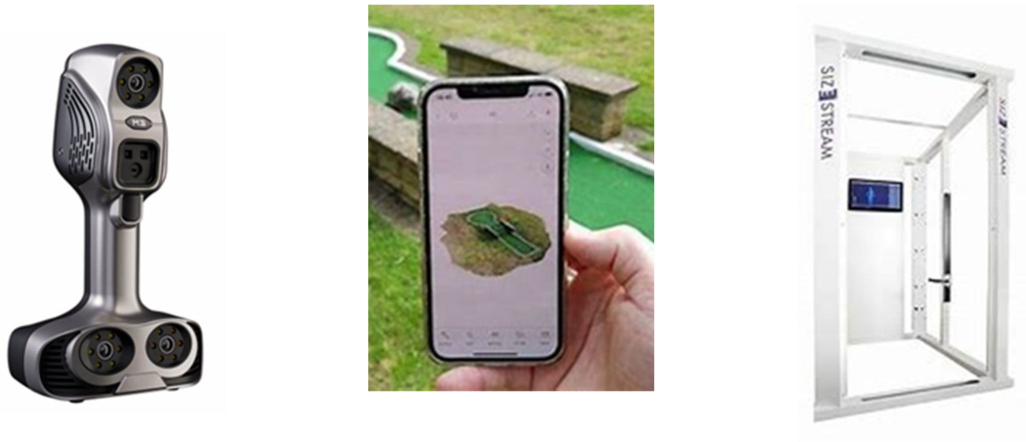
In the apparel sector, as employed in research conducted by Pei et al., 3D scanning can help to assess the impact of various bras on breast contour. The study used 3D scanning to observe the changes in shape between the nude, structured bra, and soft bra conditions. By analysing the contour maps produced by scanning, it gave quantitative insights into alterations in shape, making it possible for the prediction of breast shape while wearing various bras. In this way, 3D scanning helps the apparel sector to understand the interaction between bodyforms and undergarments, therefore enhancing the design and customisation of bras to achieve customer comfort [9].

2. Approach

Extensive research has been conducted to scan the human body. However, when examining the relationship between the body and clothing, it is essential to consider the ability of the scanner to also capture the garment. This paper examines portable body scanners, 3D body scanners, mobile-based photogrammetry, and app-based photogrammetry scans.

2.1.1. Portable scanners

I-real is a portable scanner utilizing White Light Technology, equipped with three sensors and three cameras, weighing 850 g. This device provides output formats in OBJ, STL, and PLY, specifically designed for applications such as reverse engineering, cultural artifacts, and virtual visualization.



a b c

Fig. 4. a) Portable 3D scanner, b) Mobile based photogrammetry software; c) 3D body scanner

2.1.2. Mobile based photogrammetry

The mobile application Polycam employs photogrammetry technology and provides output formats in OBJ, PLY, or GLTF. The software accommodates a wide range of applications such as the development of video game characters, special effects, 3D scanning environments, drone mapping, and 3D interior designs, thereby offering adaptable solutions for the production of digital content.

2.1.3. Full Body Scanner

The Size Stream full-body scanner is a non-portable imaging device that employs infrared technology and is outfitted with 14 sensors. It has fast scanning capabilities, results are produced within 10-15 seconds. This scanner provides highly effective and accurate full-body scanning capabilities for a wide range of applications.

2.1.4. Software based photogrammetry

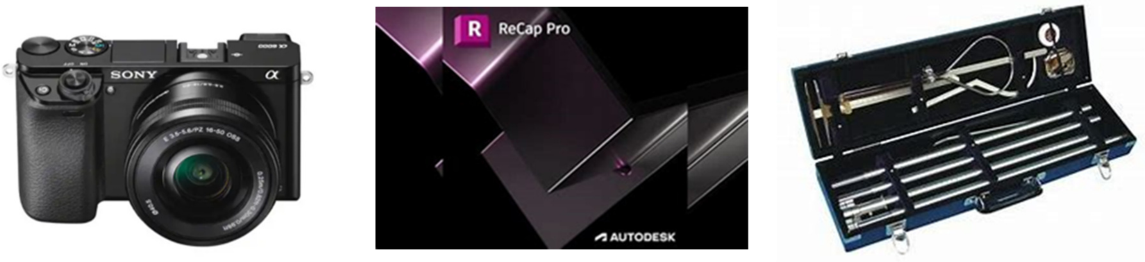
The Recap 3D software application is a photogrammetry-based tool used for scanning. This Recap 3D software provides output formats in OBJ, STL, and PLY and allows flexible compatibility and precise 3D reconstructions.

2.1.5. DSLR Camera

The Sony A6400 camera, which is renowned for its 24.2-megapixel APS-C Exmor CMOS sensor and 4K video recording capabilities, was used to capture images for the Recap 3D scanning process, guaranteeing accurate 3D reconstructions by acquiring high-quality visual data.

2.1.6. Anthropometer

An anthropometer is a highly accurate measuring instrument that is used to identify the body shape precisely. Therefore, it has a vital part in the accuracy test by offering exact measures of height, length, and width for the purpose of comparison and validation.



a b c

Fig. 5. a) Camera, b) Application based photogrammetry c) Anthropometer

2.2. Software Applications

2.2.1. Zeiss Inspect Software for GOM Imaging

ZEISS INSPECT functions as the primary element of the metrology software package, accompanied by specialised versions tailored to different industries. The software applications GOM Inspect and GOM Correlate have been upgraded to ZEISS INSPECT Optical 3D, ZEISS INSPECT X-Ray, and ZEISS INSPECT Correlate, respectively. In this study, it was employed to align several scans.

2.2.2. Geomagic Control X

The software package known as Geomagic Control X was developed by 3D Systems. Its major focus is on converting 3D scan data, point clouds, and mesh data into functional 3D models. This study used Geomagic Control X to perform heat mapping for reliability analysis and measurement.

2.2.3. Meshmixer

Autodesk Meshmixer is a multifaceted 3D modelling software which is known for its powerful editing and mesh modification properties. User-friendly integration, manipulation, and enhancement of 3D models for diverse applications are some other advantages of this software. In this paper, this software was used to enlarge the scanned data generated, providing meticulous manipulation of scaling and refining 3D models for perfect alignment and analysis.

3. Data analysis

3.1. Evaluation of Quality and Dependability of Various 3D Scanners

This research phase began with the evaluation of the precision and dependability of specific scanners, namely the i-Real White Light Scanner, Size Stream Full Body Scanner, Polycam Application Scanner, and Recap 3D Photogrammetry Software Scanner. The research, which was conducted in actual environmental settings, began with measuring the proportions of the body form using an anthropometer before scanning with the chosen equipment. Scanned files obtained from photogrammetry scanners like Recap scanner and Polycam scanner were enlarged in size in order to enhance the comparability with measured data. Accuracy of each scanner was assessed by comparing the real measurements with the scanned data obtained. An evaluation of reliability was conducted by heat mapping several scans of the body shape to guarantee uniformity throughout various scanning sessions.

During study it is found that full body 3D scanners are not able to produce scan image of the garment since it has sensors only at front and back. The side of the garments are not captured. So it is not able to create OBJ file.

Photogrammetry is able to capture all the sides but it could not create the actual size of the body or garment. Also the scanned images are not upright and need to be aligned for further processing.

3.1.1. Polycam and Recap Scanned Files Scaling Up

During the Polycam and Recap scanners evaluation, the scanned files were altered to enhance their comparability with real measurements, particular emphasis was placed on the central back to waist length. The measurement for this length was found to be 39.4 cm by manual means. Polycam scanner produced an initial measurement of 0.00091 cm, which corresponds to a scaling factor of around 43,296.7. Furthermore, the Recap scanner's initial measurement was 0.02835 cm, providing a scaling factor of approximately 1,389.77. Later, Autodesk employed these scaling factors in the Meshmixer software to modify the scanned files obtained from Polycam and Recap, ensuring that the dimensions precisely represented the real measurements for more dependable analysis.

3.1.2. Precision of several optical scanners

Table 1. Comparison of bodyform measurements using mean values

Measurement Item	Sl No.	Category	Measurements in cms			
			MANUAL	POLYCAM	I-REAL	RECAP
Height from Floor	1	Shoulder	138.37	139.39	138.62	138
	2	Bust	119.83	118.83	119.54	120.49
	3	Waist	104.4	104.99	104.42	105.72
	4	Hip	83.17	85.54	83.38	82.48
Segment Length	5	Between front axillary folds	31.03	30.55	31.09	32.77
	6	Between back axillary folds	31.2	30.76	31.26	32.68
	7	Horizontal length between nipples	19.77	20.8	19.65	20.72
	8	Center Back Waist Length	39.4	40.58	39.76	40.12
	9	Outseam	104.47	103.2	104.29	105.77
Circumference	10	Bust	101.6	102.85	101.32	102.3
	11	Waist	77.17	78.6	77.44	78.46
	12	Hip	102.2	101.51	102.16	103.76
Width	13	Shoulder	36.6	37.78	35.93	37.6
	14	Chest	32.13	33.55	32.18	31.43
	15	Waist	24.57	23.46	24.71	25.63
	16	Hip	34.27	35.51	34.48	35.13

3.1.3. Comparative analysis

The measured disparities between all scanners and anthropometer readings were computed and arranged in a table. According to ISO 26085 standards, measurements that exceeded beyond the permissible deviations for height (0.4 cm), width (0.4 cm), depth (0.5 cm), big circumference (0.9 cm), small circumference (0.4 cm), and length (0.5 cm) were detected and highlighted in grey to indicate inconsistencies.

The I-Real scanner outperformed other scanners in terms of precision , as seen by measurements falling below permissible error thresholds and the lowest standard deviation. In contrast, the Polycam and the Recap 3D scanner produced measurements that exceeded the permitted margin of error, implying diminished levels of accuracy and precision. In the apparel business, these results highlight the need of selecting a scanner with high accuracy and dependability for accurate body shape measurements.

3.1.4. Scanning Reliability Assessment

To perform the reliability assessment, two sets of scanned data from the same scanner were uploaded into the inspection software Geomagic Control X and was subjected to heat mapping in order to detect the areas of variations which was indicated by different colour gradients. Based on the heat mapped data, the Geomagic Control X software automatically computed the lowest deviation, maximum deviation, and standard deviation.

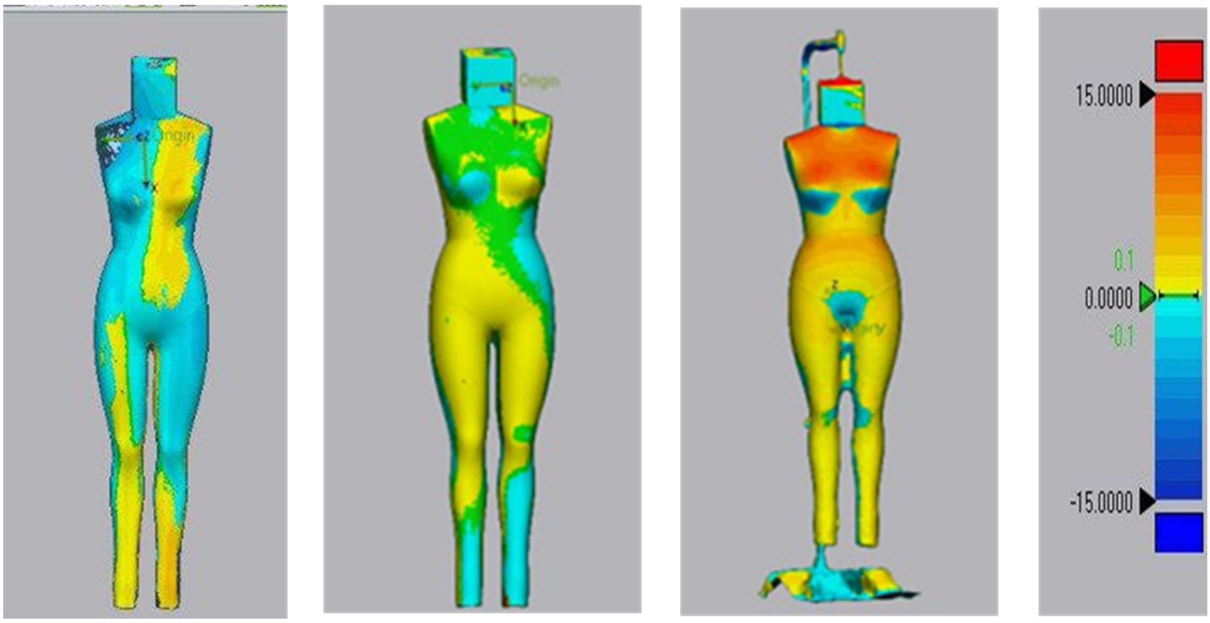


Fig. 6. displays heat mapping of scanned data obtained from (a) Polycam, (b) i-real, and (c) recap 3d.

Within the heat mapping examination of the Polycam scanner, most of the body form scans had a light blue and yellow colouration, suggesting a high level of consistency.

Table 2. Variation analysis of different 3D scanners

	PolyCam	I-REAL	Recap
Minimum deviation	-5 mm	-5.6691 mm	- 16.8547 mm
Maximum deviation	5 mm	5.6986 mm	16.8539 mm
Measured average deviation	- 0.2981 mm	0.1956 mm	0.8667 mm
The Root Mean Square Departure	2.3542 mm	0.5384 mm	4.0132 mm
Standard deviation	2.3352 mm	0.5017 mm	3.9185 mm

Analysis of the I-REAL scanner's heat mapping revealed primarily green and yellow colours in the body shape scans, suggesting little variations within the defined tolerance range.

The heat mapping analysis of the Recap scanner demonstrated that majority of the body form scans had a yellow colour, suggesting a high level of consistency in the readings. Nevertheless, distinct variations were seen in the breast area, characterised by red and dark blue shades.

The comparative analysis of the 3D scanners revealed that the I-REAL scanner is the most reliable option. It achieved an average deviation of 0.1956 mm, a root mean square deviation of 0.5384 mm, and a standard deviation of 0.5017 mm, indicating minimal variations. In contrast, the Polycam scanner exhibited a moderate level of reliability, with an average deviation of -0.2981 mm, a root mean square deviation of 2.3542 mm, and a standard deviation of 2.3352 mm. The Recap scanner demonstrated the lowest level of dependability, particularly in the chest region, with an average deviation of 0.8667 mm, a root mean square deviation of 4.0132 mm, and a standard deviation of 3.9185 mm. Hence, the exceptional accuracy and reliability of the I-REAL scanner establish it as the most superior choice for body form scanning.

Table 3. Comparative Analysis of Various 3D Scansers

SCANNER	TECHNOLOGY USED	INSTALLATION	MOBILITY	TIME
Polycam	Photogrammetry	Mobilephone Application	Portable	5-15 minutes
Recap	Photogrammetry	Desktop Application	Portable	10-30 minutes
iReal	White Light / Infrared	Handheld Device	Portable	Max 10 minutes
Size Stream Full Body Scanner	Infrared	Booth Scanner	Non - portable	10-15 seconds

3.2. Analysis of Alignment Issues in Portable Scanner

A sequence of experiments was performed in order to address the alignment problems encountered by portable scanners and to improve the precision of scanned data produced by portable scanners. Initially the experiment was performed by attaching crossmarks on paper to the body form, anticipating that these would act as reference points for alignment using a '3-point system.' Unfortunately, the eventual result faced a notable constraint: the inspection software was unable to detect the crossmarks in the scanned data, making this approach unfeasible. The absence of visible markings provided significant challenges in attaining precise alignment among the several images, therefore emphasising the necessity for a more efficient method.

The second experiment was performed using compact 3D projecting models, such alphabet toys, as reference points for alignment. The anticipating that their specified measurements would enable the recognition of x-y-z geometric planes. However the eventual result exposed a notable constraint: the compact dimensions and curved contours of these objects led to uneven edges in the scanned data, therefore undermining the alignment procedure. Despite the potential advantages of these objects, their practical use is limted by issues such as inaccurate alignment and inaccuracies caused by curvature, which restrict their efficacy in real-world applications.

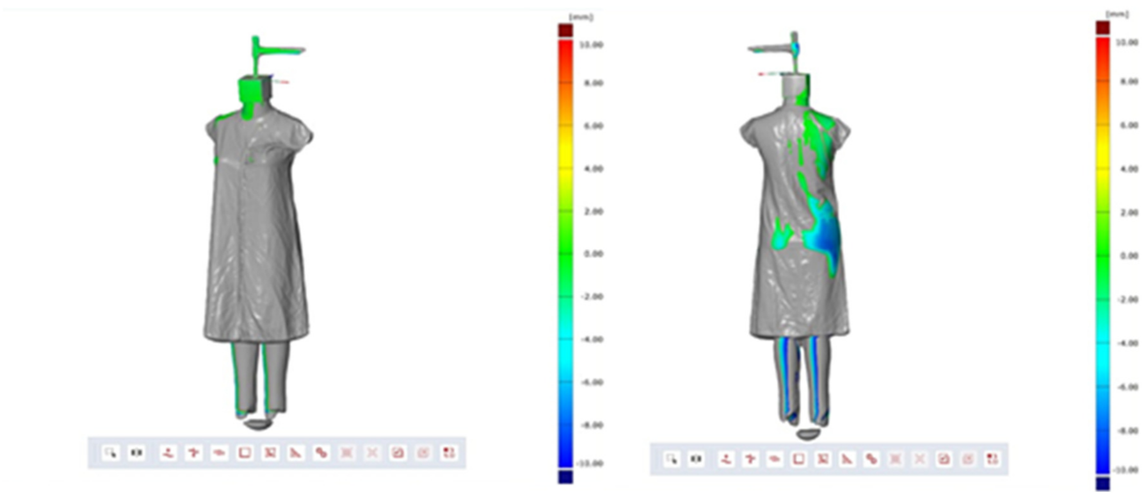


Fig. 7. Alignment using a Cubic box

By contrast, the third experiment was performed using a cubic box as a reference object, which demonstrated a high degree of success. By positioning the box on the body form during scanning, the sharp edges of the box served as distinct reference points that greatly enhanced the precision of alignment. The box was placed fixed immobile.This to ensured the uniformity even while scanning attired body models, successfully resolving the problems faced in prior experiments. This approach exhibited a dependable resolution for aligning scanned data, effectively addressing the obstacles posed by curvature and visibility that had impeded previous attempts.

4. Findings

This study evaluated several 3D scanners used in clothing applications, assessing their effectiveness over several stages.

To address the alignment problems, experimental techniques such as cross markings, miniature 3D projecting objects, and cubic boxes were implemented. While the cubic boxes proved effective, the other methods faced limitations due to software visualisation problems or object properties.

For accuracy evaluation, manual anthropometric measurements were compared with data generated by the scanners. The portable 3D scanner demonstrated exceptional precision, with readings falling under the acceptable margin of error, in contrast to the photogrammetry.

The heat mapping analysis revealed that the portable 3D scanner had the highest level of reliability among the 3D scanners examined, exhibiting low variations and superior precision in scanning body forms.

The analysis indicated that the fabric prints had minimal impact on scanning outcomes, while the main factor influencing quality was the type of scanner used. The portable 3D scanner generated more defined garment folds than other scanners, emphasizing its superiority.

By contrast, although photogrammetry offers free options with reasonable scanning speeds and mobility, the handheld scanner distinguishes itself with its rapid scanning capabilities, albeit at a higher price. On the other hand, the Size Stream full-body scanner delivers exceptional efficiency for rapid scans of the human body but not able to scan the garments also sacrifices portability.

5. Constraints

Scanning Compatibility: The research had constraints in investigating various scanners, particularly the Size Stream full-body scanner, which was unable to detect the clothing because of its design specifically tailored for scanning human bodies.

Photogrammetry Software Limitations: Some photogrammetry software programs failed to generate accurate findings because to fluctuations in the camera radius during image acquisition. In the absence of reliable camera tracking or a revolving platform, precise scanning results would be unattainable.

The project's breadth and the extent to which various scanning methods could be studied were limited by resource restrictions, encompassing hardware limits and software compatibility difficulties.

6. Conclusion

In conclusion, the study conducted a thorough examination of different 3D scanner available in the market, emphasizing on their accuracy, precision and dependability. With low deviations and expectional accuracy in scanning body forms, The handheld scanner has been identified as the most accurate and dependable choice. Notably , the fabric prints on garments had no obvious impact on the scanning results, showing the importance of type of scanner in determining the scanning quality level. Nevertheless, the study was unable to thoroughly examine all sorts of 3D scanners due to restrictions and resource limitations. Future-oriented, it is crucial to overcome these constraints and advance 3D scanning technology for apparel purposes.

References

[1] M. Abdel, "3D laser scanners: history, applications, and future," *Assiut University*, 2011, https://doi.org/10.13140/2.1.3331.3284.

[2] K. P. Simmons and C. L. Istook, "Body measurement techniques: Comparing 3D body-scanning and anthropometric methods for apparel applications," *Journal of Fashion Marketing and Management: An International Journal*, vol. 7, no. 3, pp. 306-332, 2003, doi: https://doi.org/10.1108/13612020310484852.

[3] Z. Fourie, J. Damstra, P. O. Gerrits, and Y. Ren, "Evaluation of anthropometric accuracy and reliability using different three-dimensional scanning systems," *Forensic Science International*, vol. 207, no. 1-3, pp. 127-134, 2011, http://doi.org/10.1016/j.forsciint.2010.09.018.

[4] N. D'Apuzzo, "3D body scanning technology for fashion and apparel industry," in *Videometrics IX*, vol. 6491, pp. 203-214, SPIE, Jan. 2007, http://doi.org/10.1117/12.703785.

[5] D. E. Kim, K. LaBat, E. Bye, M. Sohn, and K. Ryan, "A study of scan garment accuracy and reliability," *The Journal of the Textile Institute*, vol. 106, no. 8, pp. 853-861, 2015, http://doi.org/10.1080/00405000.2014.949502.

[6] M. A. B. Ebrahim, "3D laser scanners' techniques overview," *Int. J. Sci. Res.*, vol. 4, no. 10, pp. 323-331, 2015.

[7] C. L. Istook and S. J. Hwang, "3D body scanning systems with application to the apparel industry," *Journal of Fashion Marketing and Management: An International Journal*, vol. 5, no. 2, pp. 120-132, 2001, https://doi.org/10.1108/EUM0000000007283.

[8] M. Horstmann, A. T. Topham, P. Stamm, S. Kruppert, J. K. Colbourne, R. Tollrian, and L. C. Weiss, "Scan, extract, wrap, compute—a 3D method to analyse morphological shape differences," *PeerJ*, vol. 6, p. e4861, 2018, https://doi.org/10.7717/peerj.4861.

[9] J. Pei, J. Fan, and S. P. Ashdown, "Detection and comparison of breast shape variation among different three-dimensional body scan conditions: nude, with a structured bra, and with a soft bra," *Textile Research Journal*, vol. 89, no. 21-22, pp. 4595-4606, 2019, https://doi.org/10.1177/0040517519839398.