Survey on 3D Scanning and Web3D Interfaces for the Apparel Industry

Steve McQueen and Felix Hamza-Lup

December 3, 2018

Survey on 3D Scanning and Web3D Interfaces for the Apparel Industry

Steve McQueen†
Georgia Southern University
Savannah, Georgia, U.S.
sm16504@georgiasouthern.edu

Felix G. Hamza-Lup
Georgia Southern University
Savannah, Georgia, U.S.
fhamzalup@georgiasouthern.edu

ABSTRACT

3D scanning technology is becoming mainstream in many application domains. Since the advent of Web3D in recent years, it is possible to develop 3D web-based user interfaces that can improve user interaction and facilitate the user decision process through 3D object visualization and animation. As 3D scanning technology is becoming mainstream, the possibilities to move real objects into the virtual 3D world are emerging very fast. With the rapid growth of e-commerce, web-based 3D user interfaces carry a huge potential for rapid and widespread adoption.

This paper provides a review on 3D scanning technology and a survey of Web3D technology (e.g. X3D) in applications targeting the apparel industry, from clothing design and manufacturing to online 3D user interfaces for customization and apparel e-commerce.

KEYWORDS

3D Scanning, Body Scanning, 3D models, Web3D, Apparel, E-commerce

1. Introduction

3D scanning technology facilitates the rapid creation of 3D objects from the physical world. Specifically, a 3D scanner is a device that digitizes the physical world using lasers or x-rays and generates a point cloud that is later converted to a polygonal mesh. The apparel industry in particular, began exploring in recent years the possibility to enhance the user experience of online shopping for clothing, as well as clothing design using 3D interactive interfaces. Web3D offers an unparalleled opportunity to develop revolutionary e-commerce 3D web-based storefronts and facilitate collaborative clothing design, tapping into the 390 Billion US projected apparel market [1]. This paper provides a survey of existing technologies, as well as research efforts linked with 3D scanning technology, and Web3D tools and projects targeted towards revolutionary Web3D user interfaces for the apparel industry. The paper is organized as follows: in Section 2, we are presenting related work and research projects for body scanning. Section 3 presents in detail the existing 3D scanning technologies, followed by the human body shape modeling techniques in Section 4. In Section 5, we focus on a set of methods and propose a set of guidelines for designing Web3D interfaces for the apparel industry.

2. Related Work

Many frameworks to model the human body shape exist. In particular, there is a trend to develop an interactive modeling interface for generating a 3D corresponding human body shape as output based on body sizes inputs [2]. This parametric human body shape modeling system introduced a method for correlating body shape and body sizes, by establishing an improved parameter optimization technique for the model generation process. Another proposed framework is to estimate 3D body shapes from dressed-human silhouettes using a database containing many pairs of 3D naked and dressed male bodies for a few clothing types, and a learned regression function to predict 3D landmark positions with 2D dressed-human silhouettes [3]. Past frameworks achieved good reconstruction results in body measurements and produced an estimation error within the size tolerance of the apparel industry. Such frameworks contribute to the area of human body shape estimation and cloth simulation.

Several projects were devoted to developing online 3D scanning systems, however not much work has been devoted to developing low-cost offline 3D scanning systems. Offline 3D scanning systems are more suitable for apparel and textile industries because they may lead to the improvement of mass customization of made-to-measure clothing. A particular test [4] configured a system to test the usefulness of close range photogrammetry for 3D body scanning for custom-made garments. The conclusion researches derived from his results shows that using photogrammetry accurately captures enough 3D information for tailors to make custom-made garments. Others Blanz et al. [5] gathered 3D human face scan data and captured the shape variation by analyzing them using principal component analysis (PCA). The foundation of this work is based on the consistent mesh generation technique, which ensures identical topologies and mesh connectivity's of the example models. By generating a consistent mesh structure for every face scan sample, one can successfully construct a homogeneous face model database from the samples. Using this database, one can analyze and extract the dominant variables determining the facial shape.

Based on these variables, a 3D morphable face model may be generated [2].

The work of Lin and Wang [6] presents an approach for evaluating clothing fit on 3D human models. Representations of several different sized clothing were compared between the actual human body and virtual model of the human body to evaluate the virtual try-on clothing. The quantitative data collected from the vacant space between the clothes and the human body, is used to perform real and virtual body fit evaluations in the virtual try-on clothing system. The clothing information obtained in this study may be used for the development of human-centered design products in the apparel industry.

The work of Xu, Li, et al. [7] provides a new way of measuring the human body and a reconstruction method. They proposed a 3D human body reconstruction using a smart vest in front of a binocular stereo system. Geometric information is obtained from stereo vision-based methods, and a 3D human model is automatically generated.

3. Survey on 3D Scanning Techniques

There are several industries incorporating 3D scanning technology into their applications: media, entertainment, healthcare, fitness, gaming, fashion and apparel. In the media and entertainment industry, real actors are substituted with virtual ones in a film [8]. In the healthcare industry, hospitals use magnetic resonance imaging (MRI) scanning to generate 3D models of their patients for diagnosing and preoperative planning. The gaming industry incorporates 3D scanning technology to achieve realistic virtual environments, humans, and other desired objects for more immersive experiences. There are many companies in the fashion and apparel industries incorporating 3D scanning technology [9, 10], for example, Miller's Oath, Astor and Black, and Alton Lane use 3D scanning to create general-purpose custom clothing [11] while Brooks Brothers utilizes it for suit tailoring and Victoria's Secret utilizes the technology for generating product recommendations [12]. 3D scanning is used to develop custom swimsuits [13] and even edible clothing [14]. Scanning is utilized to generate clothing for special applications, e.g. tightly fitting high performance sportswear [15], to assess the clothing used by firefighters, hazmat workers and warfighters [16]. 3D scanning allows sizing for uniform selection by the U.S. Coast Guard [17], speeding up the process considerably.

3.1 Laser Triangulation

For laser triangulation, the scanners use either a laser line or a single laser point to scan across an object and a sensor captures the light from the laser reflected from the object using trigonometric triangulation as illustrated in Figure 1. The technique works well for large objects that do not have reflective or retro-reflective surfaces. The laser triangulation method generates a large point cloud that requires noise data corrections before a polygonal model is obtained. One of the advantages of the method is that large area scans are possible. On the drawback side, the method requires camera calibration. Moreover, markers are placed in the environment for large area scanning, such that the point cloud can be merged at the end of the procedure. Laser scanning does not work well with reflective and retro-reflective surfaces due to the light scattering effect.

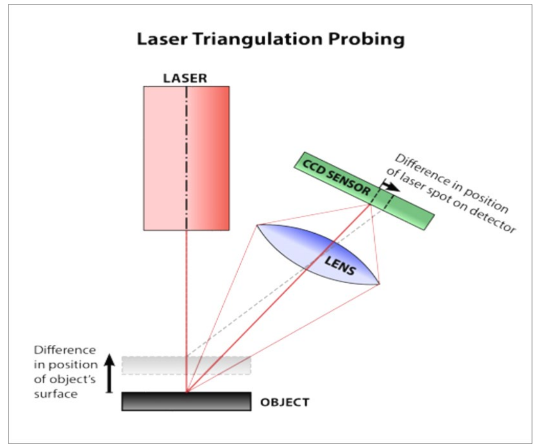

Figure 1. Scanning using laser triangulation

3.2 Structured-Light

The structured-light scanning, requires scanners to project a series of linear patterns of light onto the object and examine the edges of each line in the pattern using trigonometric triangulation as illustrated in Figure 2. The structured-light can be white or blue and is generated by a projector. Sometimes the infrared (IR) spectrum is used as the light interference is minimized and the IR pattern is not visible to the human eye, hence non-invasive

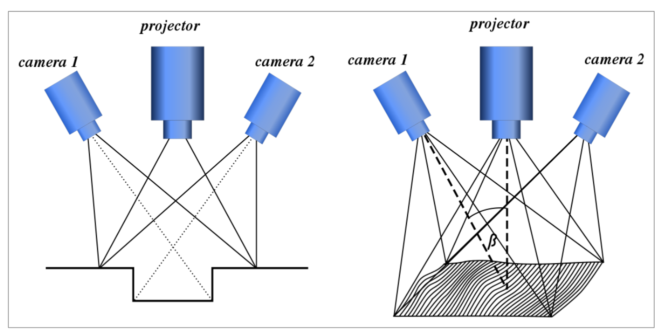

Figure 2. Structured Light Scanning

3.3 Laser-Pulse Based

This is a technique based on the time-of-flight of a laser beam. The laser beam is projected onto a surface and collected on a sensor as illustrated in Figure 3. The time of travel of the laser between its emission and reception gives the surface's geometrical information.

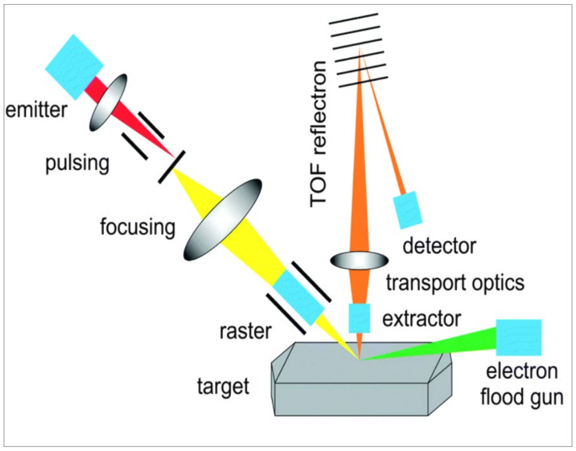

Figure 3. Laser-Pulse based scanning

3.4 Photogrammetry

Photogrammetry relies on photographic images composition into a 3D polygonal object as illustrated in Figure 4. Originally, the technique was used to generate aerial data from aerial photography. The geometric measurements of an object are computed using photographic images as illustrated in Figure 4.

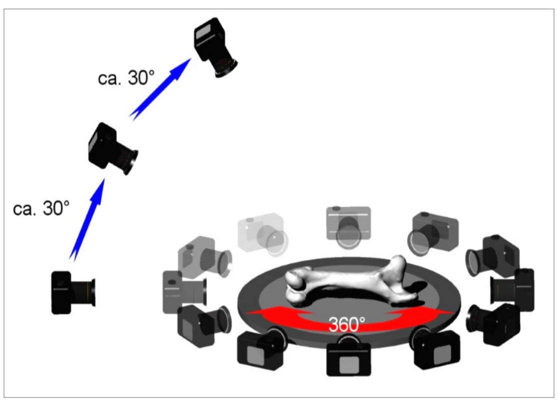

Figure 4. 3D object generation using photogrammetry

3.5 3D Scanning Techniques Comparison

3D scanning systems using laser triangulation are a good solution if the target object is in motion because the movement of the reflected light is captured into a CCD (Charge-Coupled Device, a silicon chip converts light into a pattern of electronic charges) array and analyzed to output the exact position of the object [18]. The main advantage of the laser triangulation technique is its resolution and accuracy, however, the quality of the scan depends upon the object's surface material. Surface material that reflects too much light makes it difficult to render the object in 3D. The structured-light technique is most effective when the object is stationary [19], unlike in laser triangulation, because the projector needs to take a sequence of images with different patterns of light projected onto the object to generate a 3D point cloud. The main advantage of the structured-light technique is speed and resolution; however, errors can occur if the object moves during the data acquisition process. Laser pulse-based scanners are better suited for applications needing to scan objects that are far away and dynamic. The main advantage of using laser pulse-based scanners is their capability of scanning large objects and environments, however, the main disadvantage is their slow data acquisition speed compared to the other techniques. Photogrammetry is most effective if objects are stationary, similar to the structured-light technique, but is more valuable for outdoor applications. The technology used in photogrammetry is capable of reconstructing variously scalable objects. The main advantage of using photogrammetry for 3D scanning is its precision and data acquisition speed [20], however, the quality of the photographic images depends on the resolution of the camera, the amount of ambient light available within the environment [21], and the capability of hardware processing complex algorithms to render the 3D objects.

4. 3D Human Body Modeling

Human-Centered design (HCD) is an approach to creating products and services by considering every stage of the design process through the eyes of the consumer. The approach intention is to make interactive systems usable and useful by focusing on the user needs and requirements [22]. Obtaining a model of the human body can be an important factor in developing human-centered design products. However, the main issue with obtaining such a model is developing applications to scan the human body without accruing expensive and sizable 3D scanners. Research related to human body modeling is an active area of research in computer graphics, where the focus is on a high level of realism. There are several methods employed: direct model creation, template model scaling, image reconstruction, and statistics-based modeling synthesis [2].

- **D**irect **m**odel **c**reation

The 3D model is generated directly from one of the aforementioned scanning techniques. These techniques are the most accurate way of obtaining the human body shape because they produce a 3D model with high accuracy and precision. However, the equipment is expensive and post-processing can take time, and may not be fully automated.

- Template Model Scaling

The 3D model is not created from scanning but created from the conceptions of the modeler or constructed from an existing 3D model. The 3D model undergoes deformation, scaling, and other modeling techniques to produce accurate resultant models. However, this method does not guarantee the reality or accuracy of the resultant models because the correlation between the body parts are not consider due to a lot of approximation.

- Image Reconstruction

The 3D model is created from a reconstructed set of 2D images obtained from different perspectives of the human body shape. This method primarily uses photogrammetry as the technique to extract the anthropometric data from the set of 2D images. This method is desirable because the only requirement is the set of photographic images. However, the disadvantage to this approach is the quality of photographic images.

- Statistic-Based Modeling Synthesis

The 3D model is created from a study of the probability distribution of the human body shape and variations in the human physique and pose. This method has made significant progress; however, due to the lack of large public datasets of 3D scanned human body data [23], it limits the shape variations one can generate.

5. Guidelines for designing Web3D interfaces for the Apparel Industry

Web3D technology seeks to bring engaging 3D user interfaces. It deviates from the normal 2D interactivity on the web or Web 2.0. There is a potential in the field of e-commerce to use Web3D technology because users can manipulate, view, configure, or customize their products of interest [24]. In particular, the fashion and apparel industry can adopt ways to incorporate Web3D technology into human-centered design applications. For example, shopping for clothes is a time-consuming activity: stressful and tedious for some, a leisurely pass time for others. However, efforts to facilitate consumers in the shopping process can be achieved through the development of Web3D interfaces. Since there are more online clothing retailers, many shoppers have the option to spend time buying clothes online. Manufacturers or retailers can cater to the specific needs of the consumers by developing applications for which their Web3D interfaces can allow consumers to virtually try-on clothes. This idea makes it possible for consumers to see how well their garments fit, providing first impressions on those garments, valuable visual information, and size suggestions. This can consumer decision process to purchase and help the manufacturers/retailers collect anthropometric data for each consumer making it possible for the automation of mass customization of made-to-measure clothing and improving their efficiency in garment production.

A few commercially available applications using Augmented Reality (AR) exist: FaceCake, and Fitnect. FaceCake is platform that allow consumers to virtually try-on individual or multiple products on their own images in real-time, while instantly providing relevant product recommendations within each user session for superior personalization [25]. Fitnect is an easy to use AR 3D fitting room system that allows shoppers to virtually try-on various clothes and accessories, giving them the chance to preview products without trying them on physically [26] as illustrated in Figure 5. These systems likely use human body tracking technologies in their applications [27].

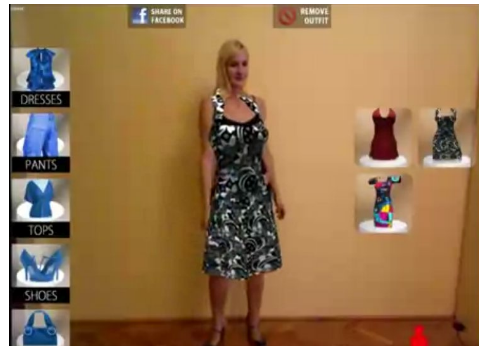

Figure 5. AR based 3D fitting room (Fitnect)

The probable reason why FaceCake and Fitnect do not incorporate 3D scanning technology into their applications is because of the high cost of implementation. Understanding the reality-virtuality continuum concept and how it relates to the cost of incorporating three-dimensionality into any developing application, one can reasonably infer that there is a cost to approximate the real environment or any object virtually or to create a 100% virtual environment. FaceCake and Fitnect are technically mixed-reality platforms augmenting reality with less costly objects (In their case, clothing) because it is easier to add virtual clothing onto an existing human than it is to approximate a human virtually from a real environment. As of now, their platforms do not use 3D scanners to scan humans, which lowered their cost, but their platforms are used effectively in apparel, cosmetics, jewelry, and accessories. Subjectively, one may question the visual aesthetics of these platforms. Clothing needs to have a high degree of realism or a level or realism to where the viewer perceive it is as real enough because the nature of clothing has many properties such as its fabric, texture, color, behavior, and etc. Using Web3D technology can extend the functionality of their augmented reality platforms along with more immersive virtual environments.

This section proposes some high-level guidelines for designing future human-centered applications incorporating Web3D technology in a 100% virtual environment unlike the human body tracking technologies used by FaceCake and Fitnect which uses augmented reality. Manufacturers or retailers can focus on:

- *Obtaining stable and reusable 3D virtual representation of their consumers (avatars) and specialized garments.*

The manufacturers or retailers can develop immersive Web3D interfaces that can allow consumers to virtually try-on clothes of their interest. Consumers will be more involved in the process of selection and customization. The Web3D environment should have:

- *Algorithms optimized for the framerate and rendering of complex polygonal meshes of the consumer and garments.*

The consumers should have the ability to:

- *Feel the texture of the fabric which can be replicated through a haptic device [28, 29].*

This may aid the consumer in their decision to purchase the clothing because the consumer knows the feeling of the fabric and can view themselves in the outfit from multiple perspectives [30]. Also, for the consumer to have a more realistic view of clothing, the Web3D environment should have:

- *The clothing fabric dynamics illustrated by deforming or animating the fabric to give the consumer a more realistic view of how the fabric will form and move around the body [31, 32].*

6. Conclusion

In this paper, we have provided a survey on 3D scanning technology, with a particular focus on the apparel industry. We provide an overview on the 3D human body modeling and the applications in web-based 3D user interfaces for the apparel design and marketing industry. With current advancements in 3D scanning we will see more Web3D based e-commerce front ends specifically in the apparel marketing and design industry.

REFERENCES

[1] "Statistics & Facts on the U.S. Apparel Industry". (2016): Statista. Web. 11 November 2018.

[2] Baek, S.-Y., & Lee, K. (2012). Parametric human body shape modeling framework for human-centered product design. Computer-Aided Design, 44(1), 56–67. https://doi.org/10.1016/j.cad.2010.12.006.

[3] Song, D., Tong, R., Chang, J., Yang, X., Tang, M., & Zhang, J. J. (2016). 3D body shapes estimation from dressed-human silhouettes. Computer Graphics Forum, 35(7), 147-156. doi:http://dx.doi.org.libez.lib.georgiasouthern.edu/10.1111/cgf.13012

[4] Percoco, G. (2011). Digital close range photogrammetry for 3D body scanning for custom-made garments. Photogrammetric Record, 26(133), 73–90. https://doi.org/10.1111/j.1477-9730.2010.00605.x

[5] Blanz V, Vetter T. A morphable model for the synthesis of 3d faces. In: Proceedings of the 26th annual conference on computer graphics and interactive techniques (SIGGRAPH 99), 1999, pp. 187–194.

[6] Lin, Y., & Wang, M. J. (2016). The development of a clothing fit evaluation system under virtual environment. Multimedia Tools and Applications, 75(13),7575-7587. doi:http://dx.doi.org.libez.lib.georgiasouthern.edu/10.1007/s11042-015-2681-7

[7] Xu, H., Li, J., Lu, G., Deng, H., Zhang, D., & Ye, J. (2018). Modeling 3D human body with a smart vest. Computers & Graphics, 75, 44–58. https://doi.org/10.1016/j.cag.2018.07.005

[8] S. Reynolds, "How Fast & Furious 7 created a digital Paul Walker to complete the movie", DigitalSpy, 2015. Available at: http://www.digitalspy.com/movies/fast-and-furious/news/a638894/how-fast-furious-7-created-a-digital-paul-walker-to-complete-the-movie/ [Accessed 1 November 2018].

[9] Filipescu, E.; Salistean, A.; Filipescu, E.; Olaru, S.; Niculescu, C. Software Solution to Assess Morphological Body through 3D Scanning Results. In Proceedings of the eLearning and Software for Education (eLSE), Bucharest, Rumania, 25–26 April 2013; pp. 391–397.

[10] D'Apuzzo, N. 3D body scanning technology for fashion and apparel industry. Proceedings of the SPIE, 2007

[11] Helmore, E. Menswear's Young Bloods Kick It Old School. Wall Street Journal, 12 February 2011. [Accessed 8 November 2018].

[12] Crease, R.P. Invasion of the Full-Body Scanners. Wall Street Journal, 21 May 2010.

[13] King, R. 3D Imaging Spreads to Fashion and Beyond. Bloomberg Businessweek, 6 October 2008.

[14] Duckworth, A. 3D Body Scanners and How to Grow Edible Clothes. The Guardian, 8 August 2010.

[15] Chowdhury, H.; Alam, F.; Mainwaring, D.; Beneyto-Ferre, J.; Tate, M. Rapid prototyping of high performance sportswear. Procedia Eng. 2012, 34, 38–43.

[16] DeMatto, A. 5 Ways Body Scanners Could Make Fitting Rooms Obsolete. Popular Mechanics, 29 June 2010.

[17] Fibre2Fashion US Coast Guard Uses Body Scanners in Measurement of Uniforms. Fibre2fashion, 12 June 2008. Available online: https://www.fibre2fashion.com/news/textiles-technology-news/newsdetails.aspx?news_id=57925 [Accessed on 11 February 2018).

[18] Jones, C. (2016, July 6). Red vs Blue Lasers: A Comparison of Triangulation Sensors. Retrieved November 12, 2018, from https://www.automation.com/automation-news/article/red-vs-blue-lasers-a-comparison-of-triangulation-sensors

[19] Pastorius, W. (2015, December 7). LMI3D. Retrieved November 12, 2018, from https://lmi3d.com/company/digital-hub/blog/structured-light-vs-laser-triangulation-3d-scanning-and-inspection

[20] 3D scanning technologies - what is 3D scanning and how does it work? (n.d.). Retrieved November 12, 2018, from https://www.aniwaa.com/3d-scanning-technologies-and-the-3d-scanning-process/

[21] Arbutina, M., Dragan, D., Mihic, S., & Anisic, Z. (2017). REVIEW OF 3D BODY SCANNING SYSTEMS. Acta Technica Corviniensis - Bulletin of Engineering, 10(1), 17-24. Retrieved from http://libez.lib.georgiasouthern.edu:2048/login?url=https://search.proquest.com/docview/1869485844?accountid=11225

[22] Human-centered design. (2018, November 15). Retrieved November 29, 2018, from https://en.wikipedia.org/wiki/Human-centered_design

[23] N. Hasler, C. Stoll, M. Sunkel, B. Rosenhahn, and H.-P. Seidel. A statistical model of human pose and body shape. CGF'09.

[24] Olivier Christmann, Emilie Loup-Escande, Romain Rolland, Etienne Yvain, Simon Richir. Using Web3D technologies for involving consumers within the innovation process: an example through an ecommerce application. International Journal of Design and Innovation Research, 2012, 7 (1), pp.1-20. <hal-01092913>

[25] Tillman, R. (n.d.). FaceCake Marketing Technologies, Inc. Retrieved November 17, 2018, from https://facecake.com/#aboutus

[26] 3D Virtual fitting dressing room / mirror. (n.d.). Retrieved November 17, 2018, from http://www.fitnect.hu/

[27] Erra, U., Scanniello, G., & Colonnese, V. (2018). Exploring the effectiveness of an augmented reality dressing room. Multimedia Tools and Applications, 77(19), 25077-25107. doi:http://dx.doi.org/10.1007/s11042-018-5758-2

[28] Discover a new type of haptics. (n.d.). Retrieved November 29, 2018, from https://www.ultrahaptics.com/

[29] Schofield, T. (2015, January 13). Retrieved November 15, 2018, from https://www.youtube.com/watch?v=zJK7IF91jmQ

[30] Mwopus follow. (2016, August 28). Wedding dress part 6/2 - 3D model by mwopus (@mwopus). Retrieved November 1, 2018, from https://sketchfab.com/models/3f1e7319ac044bcc881221b1efaeda6c

[31] (n.d.). Retrieved November 26, 2018, from https://threejs.org/examples/?q=cloth#webgl_animation_cloth

[32] (n.d.). Retrieved November 26, 2018, from https://threejs.org/examples/?q=cloth#webgl_physics_cloth