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Human Body Measurement with The Iphone 12 Pro Lidar Scanner

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Abstract. This article presents a study of the capabilities of the world's first mass-produced mobile device with an integrated LiDAR scanner, the iPhone 12 Pro, for scanning the human body. The analysis of modern software for working with the 3D sensor iPhone 12 Pro is carried out, their features and disadvantages are revealed. The possibility of constructing a 3D model of a tailor's mannequin from a point cloud obtained directly from a scanning device through the iOS Software Development Kit has been investigated. The accuracy of measuring the dimensional characteristics of a human figure using a 3D model is estimated. The quality of the iPhone 12's 3D sensor was assessed by analyzing the raw 3D sensor data using 3D design software MesLab and Rinoceros.

INTRODUCTION

Updating the assortment of clothing, increasing production efficiency, and improving the quality of clothing are always urgent tasks for the garment industry. Mass customization and product diversification are some of the most important business challenges. Designing any type of clothing always begins with the choice of initial data, the first part of which is the dimensional characteristics of the human body. The existing mechanism for obtaining the size of a human body is a laborious process, most often carried out by contact methods. Due to the widespread introduction of IT technologies into mass production, as well as the availability of modern computer-aided design (CAD) systems that implement traditional 2D and advanced 3D design and modeling, non-contact methods of obtaining information about the size and shape of the human body using 3D scanners are of increasing interest.

Several manufacturers offer off-the-shelf systems called body scanners [1]. In general, a body scanner is a 3D scanner capable of creating a 3D model of a human figure and special software that allows you to obtain the entire range of dimensional characteristics with minimal error. The introduction of such systems in the garment industry is difficult due to the high price and peculiarities in the methods of measuring the dimensional characteristics used in the garment industry in different countries [2].

Currently, smartphones and tablets are rapidly developing, which can now be used as 3D scanners [3]. This reduces the barrier to entry for the introduction of new methods of digitizing objects for private users and industrial enterprises. Apple announced the iPhone 12 Pro will start shipping on October 23, 2020. It is the world's first mass-produced smartphone with built-in LiDAR and TrueDepth non-contact 3D scanning sensor. With these technologies included

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in the latest Apple devices, the possibilities for digitizing real-world objects are even more widespread. Apple sells about 200 million smartphones a year, and the average time it takes for users to change their smartphone to a new one is about three years. Thus, in a few years, a significant proportion of smartphones will be equipped with a non-contact 3D scanning sensor.

The goal of this work was to determine the potential of using LiDAR and TrueDepth, included in the recent iPhone 12 Pro line, as a 3D scanner that would allow obtaining an accurate 3D model of a human figure for measuring its dimensional characteristics.

MATERIALS AND METHODS

There are many 3D scanning technologies. They are divided into contact and non-contact. When the highest scanning accuracy is required, coordinate measuring machines (CMM) [4] can be used. They are based on the principle of contact by measuring the surface to be tested with a probe. With high precision manufacturing processes and built-in standards, CMMs provide the highest precision in inspection processes. The number of contact points determines the accuracy, so the process can be time-consuming when testing complex structures as well as unknown shapes.

An alternative to this procedure is the non-contact method, which does not require physical contact with the surface. Non-contact methods are classified into various scanning technologies: passive (photogrammetry) and active (structured light and time-of-flight (ToF)) [5, 6]. These methods are used by various scanning systems with different capabilities and limitations.

How LiDAR works in iPhone 12 Pro includes ToF measurements, which measure the time it takes for an object, particle, or wave to travel [7]. TrueDepth uses Vertical Cavity Laser (VCSEL) [8] technology and consists of a traditional camera, infrared camera, proximity sensor and point projector, and a flood illuminator. The system is named and patented by Apple. A point projector emits over 30,000 points of infrared light that bounce off surfaces. Subsequently, an infrared camera captures these points of light again and the pattern is analyzed by software to create a depth map. Based on this depth map, a 3D model is created using machine learning algorithms.

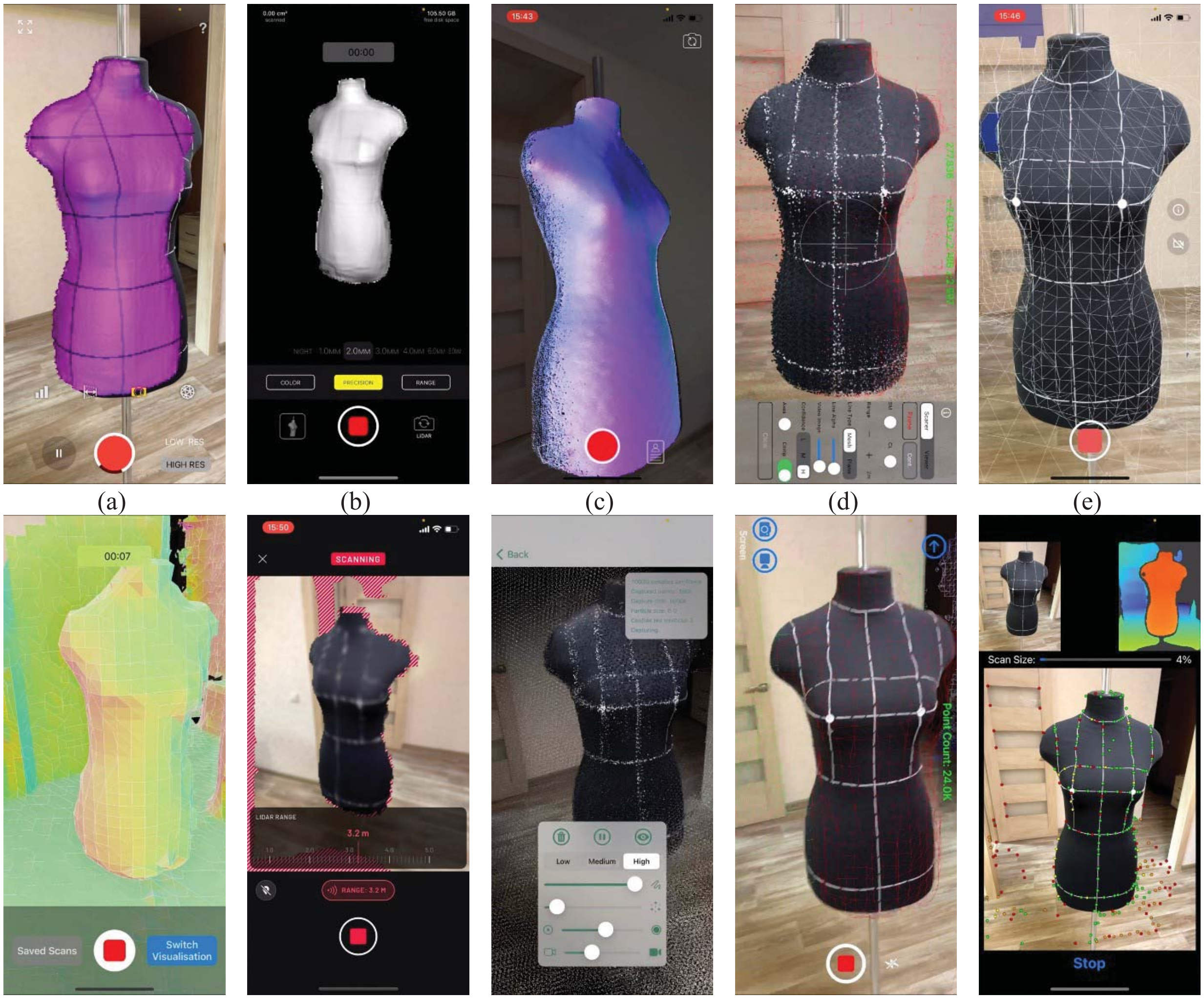
Since only one 3D sensor is available in the iPhone 12pro, it will only be able to capture a portion of the surface of the scanned object at a given time. Therefore, in accordance with the task and on the basis of the analysis performed, the following scanning method was chosen for further tests: capturing and transforming all parts of the scanned object into a three-dimensional mesh, aligning all three-dimensional grids relative to each other, combining all three-dimensional grids into a three-dimensional object.

RESULTS AND AREAS OF THEIR APPLICATION

In iOS, the operating system of Apple's smartphones and tablets, TrueDepth is primarily used for 3D authentication and face recognition, while LiDAR brings new augmented reality capabilities by speeding up plane detection. Therefore, you need to install an additional application to scan objects.

Scanning accuracy is affected by both the hardware and software of the device and external factors. Research has shown [9, 10] that such factors are reflectivity, shape, and color of an object, as well as surface texture and ambient light. In addition, the quality of scanning is affected by the distance between the object and the scanner, the trajectory of the scanner relative to the scanned object and the speed of its movement. In the process of post-processing, the quality of the 3D model is also affected by the accuracy of fitting the surfaces obtained in the process of scanning various parts of the original object. Therefore, to determine the accuracy of the iPhone 3D sensor in the laboratory, ideal scanning conditions were created. Movements of the object relative to the 3D scanner during scanning, as well as its deformation, were eliminated by using a rigid static tailor's mannequin instead of a real human body. To ensure the unambiguous position of the measurement lines, built based on the 3D model and measured by the contact method using a centimeter tape, contour lines corresponding to the measured dimensional characteristics were drawn on the tailor's mannequin with stitches. The same contour lines served as an additional marker to facilitate the alignment of 3D meshes relative to each other [11].

Were tested 10 popular applications from AppStor for 3D scanning using the 3D sensor iPhone 12 Pro, Figure 1. A test scan of a tailor's mannequin was performed using each of the applications.

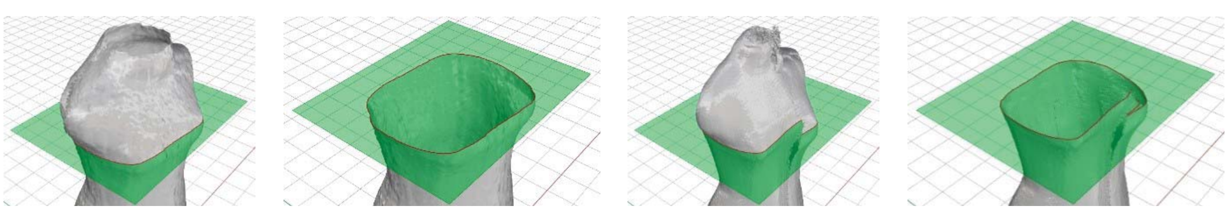


(a) (b) (c) (d) (e)

(f) (g) (h) (i) (j)

FIGURE 1. a) 3d Scanner App, b) Heges, c) Capture, d) PointCloudScan, e) Polycam, f) LiDARScanner3D, g) Scaniverse, h) PointCloudKit, i) Sakura3D SCAN, j) EveryPoint

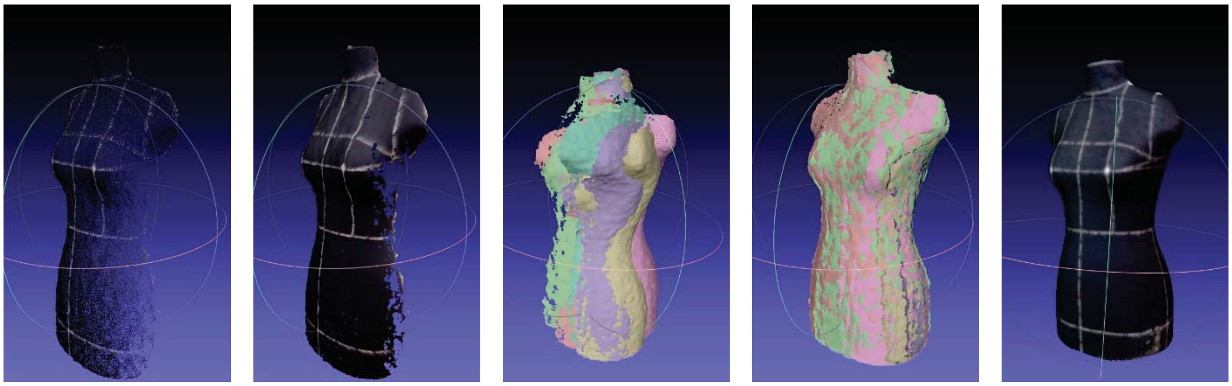
All these programs allow you to automatically build and combine 3D meshes. The resulting 3D model may turn out to be distorted. Dimensional characteristics, measured according to these 3D models, are very different from the desired ones, which casts doubt on the use of the iPhone as a 3D scanner for the purpose of designing clothes. The most common distortions of the 3D model are shown in Figure 2.



(a) (b)

FIGURE 2. a) 3D model with wrong dimensions, b) 3D model of wrong open shape due to alignment error

To assess the quality of the 3D sensor iPhone 12 Pro, within the framework of the study, using the iOS Software Development Kit [12], and raw 3D scanning data were obtained directly from the 3D sensor. Raw data is a point cloud that can be processed using 3D modeling programs. Figure 3 shows the results of processing the data of the iPhone 12 Pro 3D sensor in the MeshLab program [13].

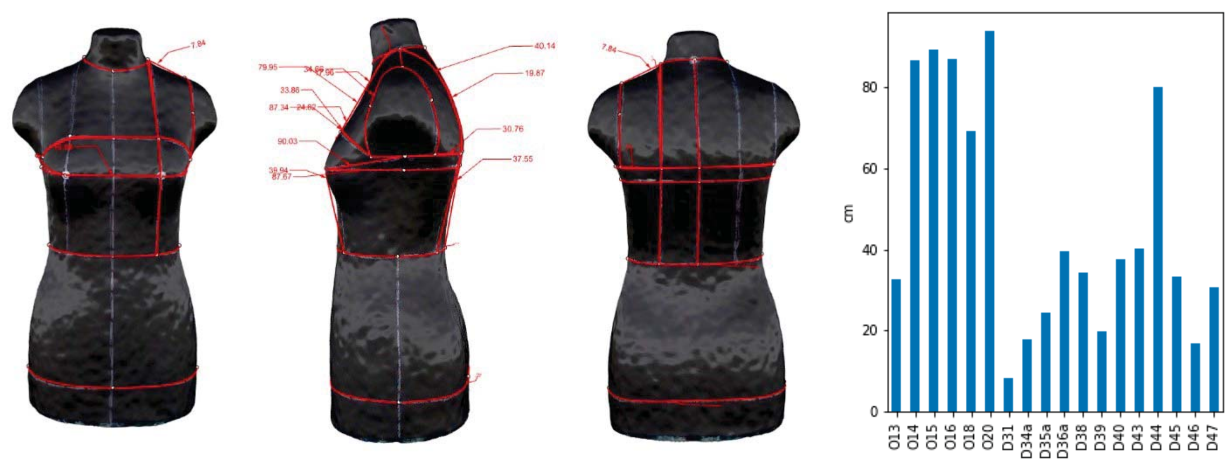


(a) (b) (c) (d) (e)

FIGURE 3. a) point clouds obtained in the process of scanning the surface of a tailor's mannequin, b) 3D mesh built on the basis of a point cloud, c) 3D meshes of all sides of the scanned tailor's mannequin, d) aligned 3D meshes with respect to each other, e) combined 3D model with texture mapping

The result of scanning an object is a point cloud, which was then transformed into a 3D mesh. The phone moves around the scanned object and scans separate parts of its surface. The process is repeated until scans of all sides of the tailor's mannequin are obtained. After that, the 3D meshes are aligned relative to each other. At the final stage, 3D meshes are combined into one object and textures are applied.

Measurement of the dimensional characteristics necessary for the design of clothing was carried out in a semi-automatic mode using the Rhinoceros 7 CAD system [14]. The required anthropometric levels were set manually by the operator on a 3D model in Rhinoceros 7. To automate the process of measuring a dimensional characteristic in the environment of the graphic editor of algorithms Grasshopper [15], a specialized module was developed that allows, based on previously specified anthropometric levels and a computer 3D model, to construct contours of dimensional characteristics and measure their length (Figure 4).



(a) (b) (c) (d)

FIGURE 4. a) front view of a scanned tailor's mannequin with measured dimensions, b) side view of a scanned tailor's mannequin with measured dimensions, c) back view of a scanned tailor's mannequin with measured dimensions, d) boxplot of measured dimensions

Observing the scanning technology [9, 10] (the absence of reflective surfaces on the scanned object, the absence of infrared light sources, etc.), using the developed modules, 20 test scans of the tailor's mannequin were carried out. Based on the obtained 3D models, measurements were made of the girths and arc dimensional characteristics of the tailor's mannequin: neck girth (O13), first bust (O14), second bust (O15), third bust (O16), waist girth (O18), girth of the hips without taking into account the protrusion of the abdomen (O20), the length of the shoulder slope (D31), the distance from the point of the base of the neck from the side to the line of the first chest circumference in front (D34), the distance from the point of the base of the neck from the side to the nipple point (chest height) (D35), the distance from the point of the base of the neck from the side to the waist line in front (waist length in front) (D36), the arc through the highest point of the shoulder joint (D38), the distance from the point of the base of the neck from the back to the level of the posterior angle of the armpit (D39), the length of the back to the waist with taking into account the protrusion of the shoulder blades (D40), the length of the back to the waist from the back to the point of the base of the neck from the side (D43), the length of the arch of the upper body through the point of the base of the neck from the side (D44), the width of the chest (D45), the distance between the nipple points (D46), width back (D47). Control measurements of the mannequin were carried out by the contact method, using a measuring tape on the original physical model of the tailor's mannequin.

Figure 5 shows box plots illustrating the distribution of the absolute values of errors when measuring each dimension.

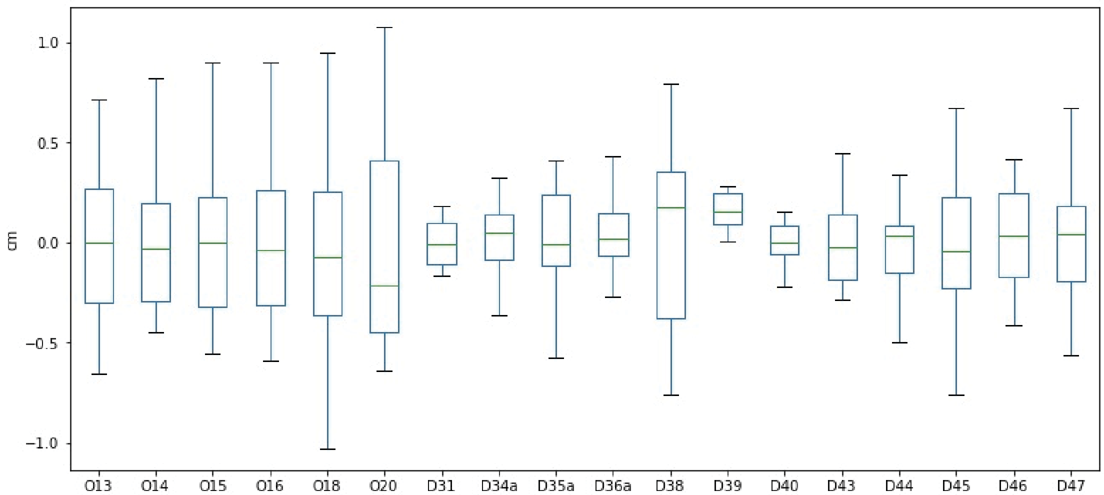


FIGURE 5. Box plots illustrating the distribution of the absolute values of errors in the measurement of each dimension.

As can be seen from Figure 5, the absolute value of the measurement error for most of the dimensional characteristics does not exceed 1 cm. When designing various types of garments, in addition to the exact values of dimensional characteristics, they are additionally used to provide free fitting. The amount of the increase depends on the degree of fit of the clothing to the figure and can range from 1 cm for clothing of an adjacent silhouette to more than 10 cm for clothing of a straight silhouette [16]. Thus, the measurement error when using the iPhone 12 Pro as a 3D scanner is satisfactory for the design of clothing and can be taken into account by the designer.

Currently, there is a lack of specialized software using this sensor. The appearance of new specialized software that automatically measures the dimensional characteristics of a human body will make it possible to massively use 3D sensors built into mobile devices. As a result, baseline scans can be performed by customers themselves, so that the manufacturer can offer them products tailored directly to their needs [17].

CONCLUSIONS

Manufacturers today are looking to differentiate their products and use more customer-centric approaches to ensure future competitiveness. Mass customization and diversification of products requires new hardware and software solutions. In this context, the availability of information about the dimensional characteristics of the human body ensures the individualization of the product with a minimum cost of money and time. In this case, the customer must be provided with 3D scanning hardware. This is provided by the iPhone 12 Pro using LiDAR and TrueDepth technologies. However, the accuracy of the scan determines the potential of the application and the possible use cases.

In the study described in this work: the analysis of modern software for working with the 3D sensor iPhone 12 Pro is described, which revealed their features and disadvantages; shows the results of evaluating the quality of the 3D sensor iPhone 12 Pro by analyzing the raw data of the 3D sensor using 3D design programs MesLab and Rinoceros. In this paper, we examined the potential of the smartphone as a portable 3D scanner. The results of the study can be used by specialists in the clothing industry involved in the process of introducing new 3D scanning technologies.

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