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RELIABILITY OF 3D SCANNING HARDWARE AND SOFTWARE TO COLLECT ANTHROPOMETRIC MEASUREMENTS

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Abstract. *In digital anthropometry there are two components present: a 3D Scanner that acquires a 3D model, and a software that obtains the measurements from this 3D model. Both influence the quality of the measurements. Given that, the purpose of this paper is to test a new method of collecting anthropometric measures using 3D scanners and readily available software. The experiment is divided in to three moments: first, the measurements from a participant are taken manually, then the same measurements are taken using the Kinect 360 and the software RecFusion Pro and 3D Measure up, and finally these are compared. As a result, we found some differences in the values obtained but all of this paper's results were better than the ones found in previous research. This demonstrates that readily available low-cost hardware and software can obtain anthropometric data agreeable with applications that entail lower precision (such as clothing).*

Keywords: *Anthropometry, 3D Scanning, Optimization, Human Factors*

1. INTRODUCTION

The use of anthropometric measures on the development of products is essential to ensure an ergonomic fit [1]. However, the issue of acquiring human measures to this effect is still an underdeveloped area, especially when it is referred to the access and usability of new technologies [2]. Some of the more utilized methods of technology-based measurements require de usage of optical measurement systems, or 3D scanning systems.

These optical measurement systems, whether based on laser or structured light, are in constant rise in the market [3]. They have high measurement efficiency with faster data collection [4] and do not require contact with the subject to be measured which avoid privacy issues. Nonetheless, the better 3D scanners are still expensive and inaccessible. To this effect some low-cost 3D Scanners, such as the Microsoft Kinect [5], have been arising [2], demonstrating good reliability and repeatability [6].

The research, development and application of 3D scanners have directly influenced several areas of technology. Within engineering, they have been used as a tool for analysis and product development through reverse engineering and enabling manufacturing through additive or subtractive manufacturing in CAD (Cad Aid Manufacturing) systems [7]. In the areas of medicine and dentistry, the scanners are used in the generation of digital models for subsequent 3D printing of prostheses, orthoses, surgical guides and study models to improve the quality of the relationship and experience of care between professionals and patients [8]. 3D scanners are also closely linked in assisting in the generation of digital models for manufacturing through 3D printing of orthotics, and other assistive devices to improve the functional abilities of people with disabilities [8]. Most of these applications are dependent of the capability of the 3D Scanners to obtain anthropometric measurements.

Traditional manual anthropometric measurement is the cause of several measurement uncertainties. These can occur either by the skill and ability of the person responsible for the measurement, by the uncertainty of the instruments used, or by the behavior of the subject during the measurement, which can also generate errors with respect to the repeatability of the process [9]. In addition to the well-being and comfort of the subject, the digitalization allows a considerably shorter exposure time when compared to the traditional measurement and without the existence of direct contact between the meter and the subject.

For this application, the Scanner acts in an indirect way since the collected data needs to be obtained through specific measurement software for this action. There are thus two components that are present, a hardware, the 3D Scanner that acquires a 3D model, and a software that obtains the measurements from this 3D model. Both the hardware and the software need to be analyzed together given the fact that they influence each other on the quality and capability of the measurements.

As already stated, low-cost scanners are more available, there have been a rise on studies on them, especially on the Kinect [1] [2] [4] [6] [10] [11] [12]. However, we could not find specific analysis of available and new software that are compatible with the Kinect and that show a good reliability.

Given that, the purpose of this paper is to evaluate a new method of collecting anthropometric measures using 3D scanners, using readily available software, and to compare this method with traditional anthropometric measurements. So, in this pa-per, we present the preliminary analysis of the RecFusion Pro [13] and 3D Measure UP [14] software, in which, after the subject is digitalized, the digital model is imported and the software itself measures the different regions of the body, and it is up to the user to choose only the ones that are necessary for his specific application.

2. LITERATURE REVIEW

The introduction of 3D body scanners has revolutionized the capture of anthropometric data since they allow automatic, rapid and contact free data collection [15] [16]. These significant advantages compared to the traditional manual anthropometric measurements have resulted in the use of 3D body scanning technology in numerous anthropometric surveys worldwide [17] [18].

As consequence of this new technology natural process, databases based on data obtained with 3D body scanners is constantly growing [9]. It is therefore of particular importance that these data exhibit a high degree of accuracy and precision. ISO 20685, the standard for 3D scanning methodologies for internationally compatible anthropometric databases, defines accuracy as the extent to which a measurement extracted from a 3D scan approximates the reference value [19].

Typically, the practitioner conducting the manual measurement should possess the skill necessary to ensure compatible measures and repeatability of the process through traditional instruments such as calipers, stadiometers, anthropometers, sitting height tables and measuring tapes [19].

To verify reliability of 3D scan-based measurements, a skilled researcher utilizing traditional instruments determines the reference value of body dimensions [9] [20]. The precision of scan-derived measurements, also referred to as repeatability, is de-fined as the difference between multiple measurements with the same 3D scanning system [17].

Accuracy and precision of the data ascertained with 3D body scanners are influenced by the factors listed in Fig. 1 and are broadly split into two main categories: Technical Variability and Human Variability [21] [22].

Factors influencing precision and accuracy	Resulting Effect	
Precision of the 3D scanning hardware		Technical variability
Performance of the data acquisition and visualisation software		
Performance of the landmarking and measurement extraction software		
Variability of the inhalation level of the human subject		Human variability
Ability of the human subject to replicate postures	Postural variability	
Body sway of the human subject		

Figure 1. Factors Influencing Precision and Accuracy. Font: [9], p.91

Previous studies have shown that body dimensions extracted from 3D body scans regularly fail to satisfy the accuracy requirements laid down in ISO 20685 for the use in anthropometric databases [17] [22] [23].

Most manufacturers offer their 3D body scanning systems as a package comprising of the scanner, controllers to operate the scanner as well as IT for data processing and storage [9]. In the majority of cases, they also provide a proprietary software package dedicated to data acquisition, anatomical landmark detection and automatic measurement of body dimensions [24].

Thus, it can be inferred that the factors influencing the technical variability (Fig. 1) are system inherent. The only remaining option for users to reduce the technical variability is to make sure that their scanning system is as up-to-date as possible and calibrated appropriately.

As for the influence of breathing, ISO 20685 stipulates that the participants should breath normally [9] [20] [9]. This is in line with the findings of McKinnon and Istook [22], who scanned subjects holding their breath at different inhalation levels and when breathing normally, they found that humans are unable to reliably replicate a certain respiration level and that breathing normally during the scanning process least compromises the data integrity.

Also, it is common practice that the subjects are verbally instructed by the scanner operator on how to adopt the scanning posture. Since they are either standing or sit-ting unrestrained on the scanner platform, variations in the posture due to body sway and the user's inability to replicate postures are inevitable [9]. Thus, in a number of studies [23] [17] [22] postural variability was found to compromise the integrity of the scan derived anthropometric data considerably.

Although it is a major advance in the area of data collection for measurement, not only anthropometrics, but in practically any desired field of study, the aforementioned factors are points which need to be properly identified and understood so that the level of precision required is reached. As well as the advantages and disadvantages of the new measurement method must be listed so that its improvement over traditional methods can be verified.

3. MATERIALS AND METHODS

The experimental method is divided in to three moments, first, the measurements from a participant are taken manually, then the same measurements are taken using the 3D scanner and the proposed software for five times, and finally these measurements are compared.

3.1 Scanning Hardware

The hardware used was one Microsoft Kinect 360, which is capable to capture the entire human body. The 3D Scanning system used with the Kinect to capture the 3D image the SDK v1.8 software for Windows [25].

3.2 Acquisition Software

The hardware used was one Microsoft Kinect 360, which is capable to capture the entire human body. The 3D Scanning system used with the Kinect to capture the 3D image the SDK v1.8 software for Windows [25].

3.3 Measurement Extraction Software

For the collection of the anthropometric measures from the model generated by the acquisition software, we used the most recent version of 3D Measure up [14], from 2017, developed by Photoetch Solutions. This is also, one of the newest software, launched in 2nd October 2017, with and exclusive system for the extraction of measures from a 3D model. The software can provide measurements of length and girth of body parts, identify standard anatomical features (head, neck, bust, waist etc.) and provide measurements of the length (head, torso etc.) and girth (chest, waist etc.) of body features.

3.4 Subject

To reduce variability, the analysis of the systems used in this paper, were made with the measurements of one subject. The subject was a 20-year-old female, with a height of 1.59m and a weight of 50kg. During the measurement and scanning procedures the subject was wearing their own underwear with a tight legging and a tight top. The same clothes were used by both the manual and the 3D Scan measurements.

3.5 Procedure

The subject as asked to stand in an upright position with legs and arms slightly apart from the body [20]. Eleven body part-measurements, taken from the right part of the body, were selected for the analysis and measurement comparison:

1. Neck circumference
2. Shoulders circumference
3. Arm circumference
4. Forearm circumference
5. Wrist circumference

6. Stomach circumference
7. Hip circumference
8. Thigh circumference
9. Knee circumference
10. Calf circumference
11. Ankle circumference

To avoid errors in the repetition of the measurements and for the extraction of the same measures manually and with the scanning system, landmarks were positioned on the subject's body, one for each measurement, as shown in Figure 2. This allowed for reliability of the measurement's location.

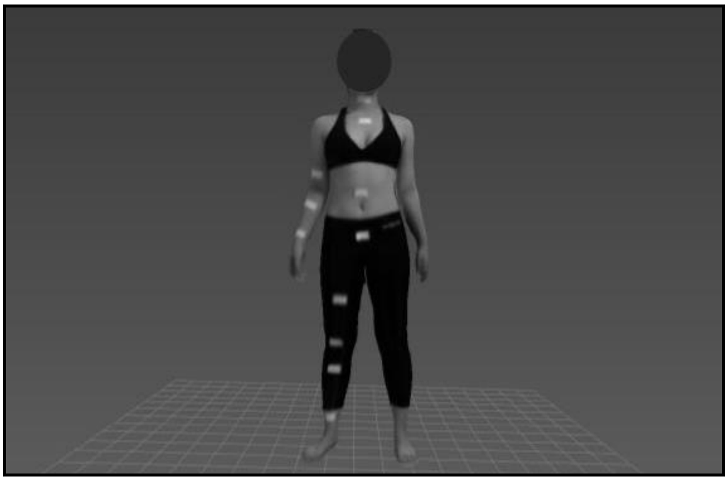

Figure 2. Landmarks Positions on subject body. Font: Authors (2018)

Firstly, the subject was measured manually using a measuring tape. The measurement was timed to allow comparison with the scanning time, since the relevant time is the time in which the subject is exposed. Following the manual measurements, the subjects as 3D scanned.
Five different scans were taken from the same subject, with intervals were the subject could move and then return to the scanning position. Each of the scan process was timed and the average time was calculated.

Figure 3. Model generated with RecFusion Pro [13]. Font: Authors (2018)

After the scanning, each model was transferred for the measuring software without the need to make any changes on the 3D image. With the software, all dimensions were collected (Figure 4) of each one of the five models. The average measure was calculated for each dimension, and the results was tabulated to be compared with the measures collected using the manually measurement system.

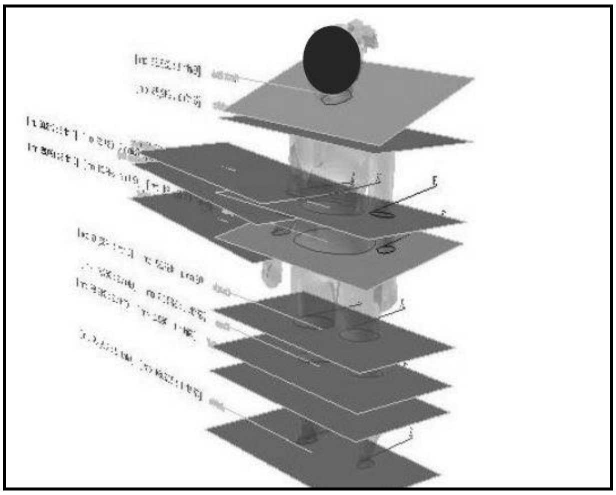

Figure 4. Dimension extraction using 3D Measure Up. Font: Authors (2018)

4. RESULTS

The results of the data collected and the comparisons are shown in Table 1.

Table 1. Data Analysis

	Bodypart	Manual (mm)	Scan average (mm)	Difference (mm)	Percentual difference
1	Neck	320	337,28	17,28	5%
2	Shoulder	945	944,3	-00,7	0%
3	Arm	240	249,02	9,02	4%
4	Forearm	225	231,2	6,2	3%
5	Wrist	155	165,28	10,28	7%
6	Stomach	650	683,34	33,34	5%
7	Waist	835	848,38	13,38	2%
8	Thigh	470	467,38	-2,62	-1%
9	Knee	395	381,72	-13,28	-3%
10	Calf	370	364,88	-5,12	-1%
11	Ankle	220	222,12	2,12	1%

As can be seen in the table, there were some differences in the values obtained. Figure 5 shows the differences between the manual and digital measurements. Some of the reasons that might explain these differences are the fact that the subject did not adopt the exact same posture during the scanning process, that the measurements were not always done in the exact same place, and that the precision of the scanning system may not be ideal. Even with the existence of landmarks, the precision of the measuring can vary.

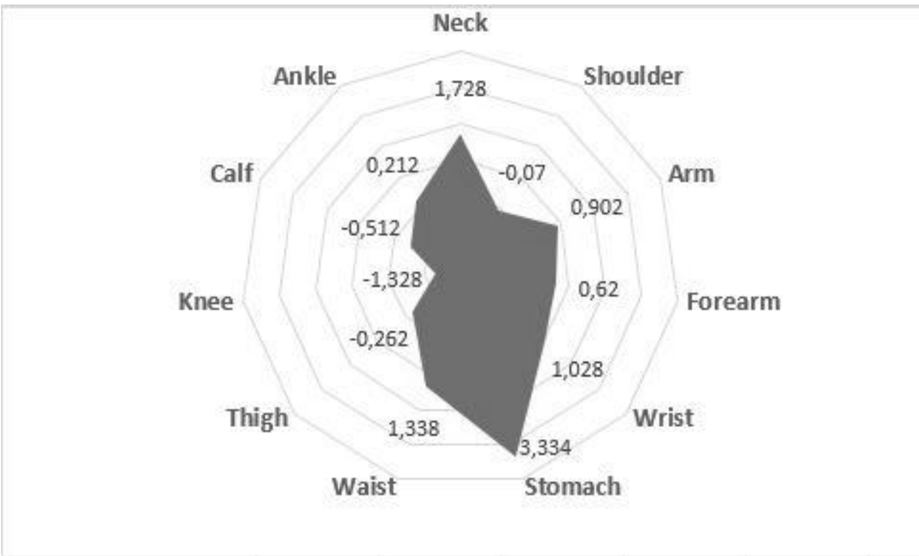

Figure 5. Difference between the Manual and the Digital Measures (mm)

Through Figure 5 It can clearly be seen that the stomach circumference had the largest difference and one of the reasons is the fact that the subject did not held her breath trough the scanning process. Because of the breathing, the diaphragm con-tracts (tightens) and moves downward. This increases the space in the chest cavity, into which the lungs expand and by that the circumference of the belly is affected.

For the time burden of process to de subject (Figure 6) there is a clear difference between the two methods. The scanning process took less than half of the time of the manual measurement. Also, while in the manual collection the user must be exposed throughout the collection and in contact with the equipment, in the digital collection the user would only be exposed during the scanning process. However, a mean reduction of 138 seconds in the digital collection process is observed, reducing the time of exposure of the user.

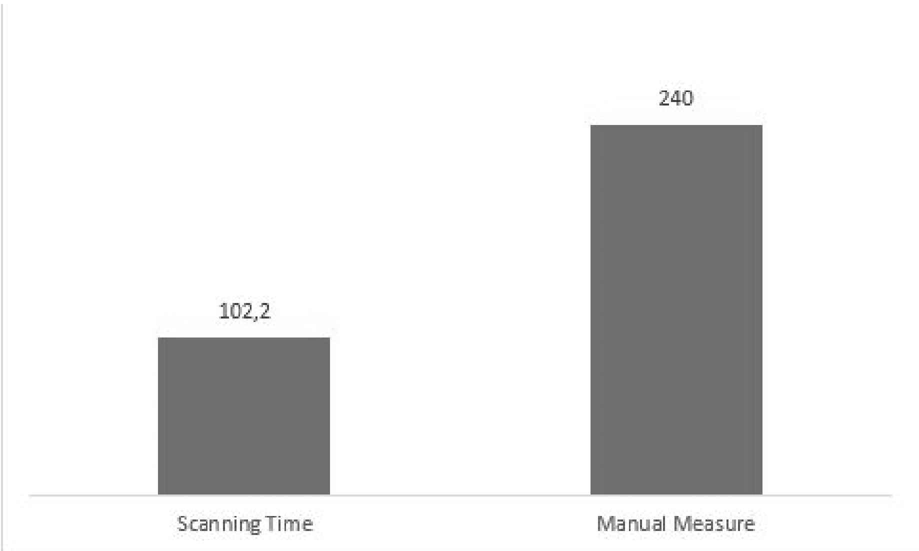

Figure 5. Comparison between the mean scanning time and manual measure time in seconds

All of these results are better than the results found by previous research [1] [2] [4] [6] [10] [11] [12]. We hypothesize that is because of the evolution of technology, specially of the software used in this study. This demonstrates that readily available low-cost hardware and software can obtain results that are agreeable with the requirements of ISO 20685 [20].

5. DISCUSSION

The analysis of the usability of new technologies [2] is a valid undertaking since there is still much to learn of the capabilities and limitations of this new products. In this work we focused mainly on the capabilities of readily available software, since it is the way in which most of the researchers will use this technology.

One of the main benefits of the 3D scanners is the high efficiency [4] which was corroborated in this study. Also, privacy [15] [16] and repeatability are other benefits that can be cited. These benefits are the ones that enabled the producing of big surveys worldwide [17] [18], which in turn popularized the 3D scanning technology. Nonetheless, the surveys [17] [18] were made using high resolution, high cost hard-ware and software which are not accessible for a wider population to develop works.

The popularity of 3D scanners nowadays is such that the International Organization for Standardization opted for developing a standard for 3D scanning methodologies [19]. Based on that, this work performed the comparison of the measures obtained from the scanner and from manual traditional methods, and from multiple measures from the same source and the same scanner, to verify repeatability.

In this work we also presented some factors that influence que quality of the col-lections and measurements [21] [22], stablishing that some of these are not in control of the researchers, since some of the calibration process is not available from these readily available software and hardware and the incapability of the participants to maintain exact positions and exact levels of respiration. Other possible errors can and were controlled such as the location of the measurements using taped landmarks and the best possible software available.

6. FINAL CONSIDERATIONS

The results of this study showed that, for most of the selected body measurements, there are differences between manual measures and digital measures. However, the difference between the two methods is not very large as was observed with all the calculations. This can mean that keeping the software up-to-date and the equipment calibrated can further reduce this difference. It can be said that, for applications that require lower levels of precision and reliability (such as clothing, where one centimeter more or less does not have major impacts), the anthropometric data collected with the body scanner can be used.

In other studies, where there is the possibility of using one of these methods, the selection of either one of them would be a valid option. Still, it should be pointed out that this study only encompassed the comparison of the manual methods with one particular body scanner and that there may be other body scanners that could give worst or better results. For future research, a larger sample of subjects should be analyzed and a validation of the processes according to ISO 20685 should be carried out.

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