Comparison of the Accuracy of a Turntable-3D-Scanner and a 4D-Scanner in the Context of Clothing Development

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Abstract

There are different 3D scanner designs and underlying technological principles for performing 3D scans. More sophisticated systems generally use more cameras/sensors and are able to are able to create very controlled conditions for the scan. Less sophisticated systems use less cameras/sensors and the scans are performed under the environmental conditions which result from the location of the scanner. More sophisticated systems can usually carry out the scan in a few fractions of a second, less sophisticated systems have scan times of around half a minute. The resulting higher cost, space requirement and general technological effort of more sophisticated systems is generally offset by a gain in greater accuracy and reliability. However, the extent to which this gain exists and what effect it has on the usability of the scan has not been examined in detail. For this reason, a parallel series measurement was carried out with a turntable 3D scanner and a 4D scanner and the results were compared. The results are presented in this paper.

Keywords: 3d body scanning, 4d body scanning, accuracy, performance

Figure 1 Left: Third frame of the 4D-scan. Right: Third Frame of the 4D-scan, rotated & translated to the first scan position. The colors show the movement between this frame and the previous one.

1. Introduction

3D-scanning is a method for contactless measurement of shape and color of solid objects. It has a rising number of applications in many different fields such as healthcare, engineering, architecture and art. One of the most important use cases is the scan and subsequent generation of 3D models of humans. The human body has a complex shape and variable elasticity. Hence, it is notoriously difficult to obtain measurements from it. 3D-scanning offers a fast and reproducible alternative to manual labor to obtain body measurements of the scanned subject. This enabled two business models in the field of textiles, which gained a lot of attention in the past years: (1) Mass customization of textiles and medical wear and (2) virtual fitting of textiles.

The technological system to perform a 3D-scan is called a 3D-scanner. There are multiple, fundamentally different designs used to build 3D-scanners. Essentially, to obtain the 3D-shape of a subject or an object, (1) its volumetric depth must be measured (2) from multiple sides. Technologies like time-of-flight, photogrammetry and active triangulation are used to obtain depth information. A common design feature of 3D-scanners are sensor arrays, which need to be directed at the scanning subject. To obtain the depth information from all sides, either (1) the scanner is moved around the subject (“handheld scanners”), (2) the subject stands on a turntable and is rotated 360° in front of the scanner (“turntable scanner”), or (3) there are multiple sensor arrays covering all sides of the subject at once ("multimodule scanner"). Each design has its own characteristic advantages and drawbacks. Handheld scanners offer more flexibility and mobility, but are more difficult to operate and may require several scanning attempts to produce a sufficient model. Turntable scanners are easy to operate and produce good results, as both subject movement and sensor position can be controlled. They are also cheaper than multimodule scanners both in procurement and operation, as they require less sensors and space. A major drawback is the scanning time: If the subject on the turntable moves during the scanning process, this will to a certain degree falsify the scanning result (see [1]). Multimodule sensors don't have this drawback, but are more expensive and also need considerably more space. [2] offers an in-depth analysis of the outlined technologies and their application in body measurement.

2. Aim

For most practical use cases of 3D-scanners in the textile domain, procurement and operation cost are of major concern. Additionally, space requirements and ease of operation are important determinants in most use cases. Turntable 3D-scanners with their lower cost, size and easy operation seem like the most favorable choice of 3D-scanner design in most scenarios. However, as (1) the subject falsifies the scan result when moving during the scan and (2) a living human subject will always move to some extent when standing on a rotating platform, this implies a reduced accuracy. As further steps in any use case rely on the accuracy of the 3D-model, it is important to understand how and to what extent the subject moves during the scan process on a turntable scanner and how this affects the overall result.

3. Material and Methods

The scanning process of a human subject on a turntable 3D-scanner was captured using a 4D Scanner. A 4D-Scanner is a special multimodule scanner capable of capturing multiple scans (frames). This allows the capturing of movement and deformation in 3D over time.

The turntable scanner used in this experiment is developed by Scaneca ([3]). It is a 3D-scanner realized with a turntable and column with RGBD sensors. 4 RGBD Sensors are built into the column. Each sensor is located on a movable horizontal axis, so that together 12 different view angles towards the turntable are realized. During the capture, several hundreds of RGBD frames are acquired. A non-rigid registration algorithm is used to compensate movements of a person during acquisition. The watertight mesh is the result of the reconstruction. The 4D-scanner used was a "MOVE4D"-system [4] located at TUD Dresden University of Technology. It can produce up to 178 3D scans per second with a distance resolution of 1-2 mm [5]. For this experiment, the framerate was set to one frame per second. Both systems are shown in Figure 2.

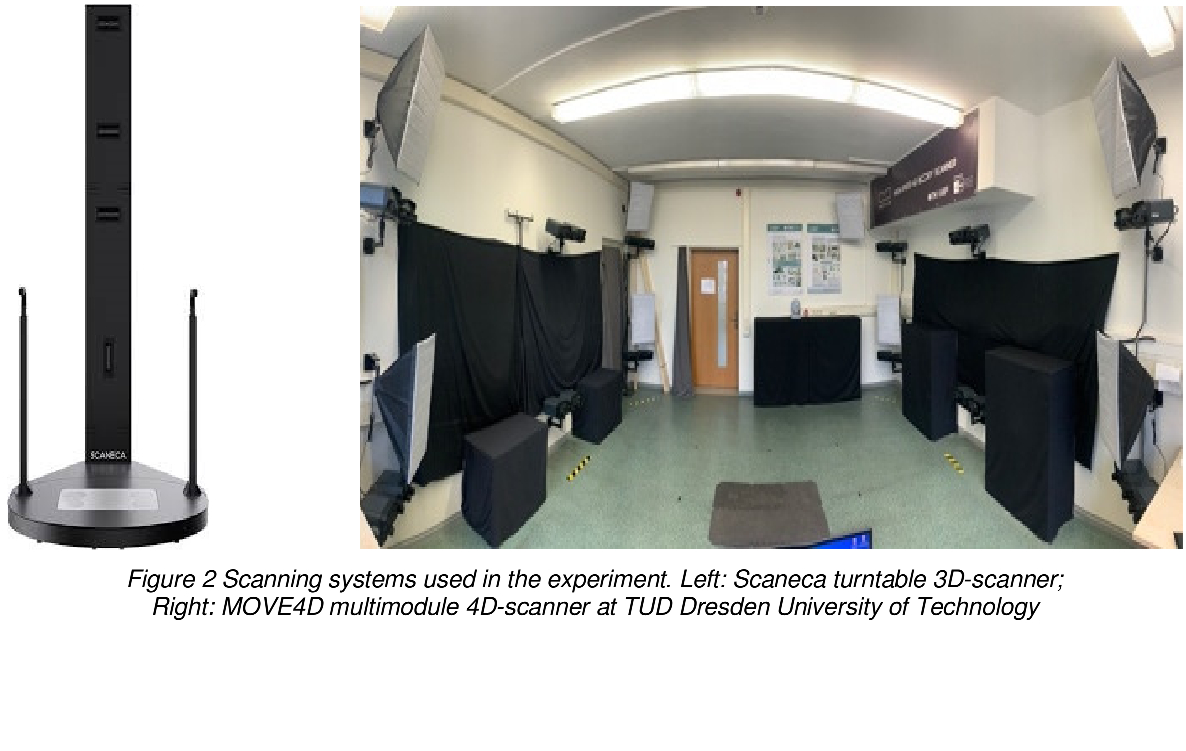

Figure 2 Scanning systems used in the experiment. Left: Scaneca turntable 3D-scanner; Right: MOVE4D multimodule 4D-scanner at TUD Dresden University of Technology

The scan was caried out on a 27-year-old male subject with a height of 183 cm and a weight of 85 kg. First, an A-pose of the subject was captured with the 4D-scanner. The turntable scanner was then placed in the scanning area of the 4D scanner. The subject then stood on the turntable. For this scan, the railing of the turntable scanner was removed and the subject was instructed to remain as still as possible with its arms hanging down. First, the capture with the 4D-scanner was launched and then the capture with the turntable scanner.

After the scans were concluded, the gathered depth information was processed into closed meshes with the respective processing software of the scanners. Some frames of the 4D-scan contained points which belonged to the turntable scanner. These were eliminated automatically by clustering the pointclouds based on point distance and keeping only the largest one. The process is demonstrated for one frame in Figure 3.

Figure 3 Cleaning fragments of the scanner out of the pointclouds. Left: Original pointcloud frame. Right: The same pointcloud frame, the points marked for disposal are highlighted in orange.

Using the A-pose captured in the beginning, the pointcloud-frames captured by the 4D-scanner were processed into a series of homologous mesh. The homologous mesh is a watertight, closed-surface, with point-to-point correspondence between subjects and along the movement sequence [5]. The resulting meshes are shown in Figure 4. Additionally, using the "MOVE4D"-software, the body measurements for each frame were calculated.

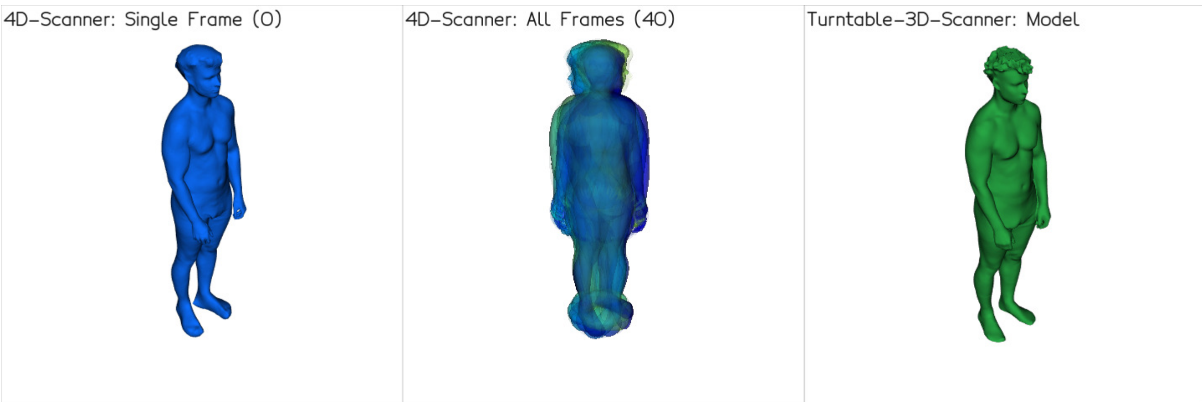

Figure 4 Meshes of the pointclouds after scanning. From left to right: First frame of the 4D-scan, all frames of the 4D-scan (overlay with an alpha of 0.5), model generated by the turntable scanner.

Most subsequent analysis of the meshes was carried out using tools from the *vedo*-library ([6]) implemented in *Python* 3.11 scripts. To analyze the movement of the subject that was not directly caused by the rotation of the turntable, the frames captured by the 4D-scanner, the rotation had to be filtered out of the mesh frames. This was done using [7]'s implementation of [8]'s method for least-squares fitting of two 3-d point sets. From all points in the homologous mesh, 1500 were randomly selected by index. The rotation and translation between the first and every subsequent (nth) frame of the scan was calculated using these same points. After obtaining the rotation matrix and translation vector, they were applied to the vertices of the nth-frame, thus aligning the nth frame to the same position as the first frame. The process is demonstrated for a single frame (frame 20) in Figure 5.

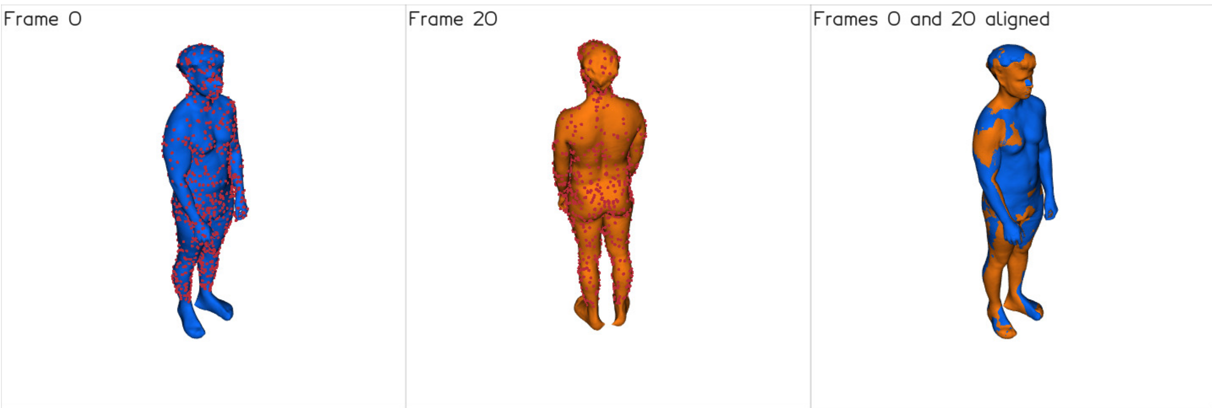

Figure 5 Alignment of the 4D-scan frames. From left to right: The first frame of the scan, the 20th frame of the scan and both frames after the rotation and translation between frame 0 and frame 20 has been computed, inversed and applied to frame 20. In the rightmost picture, it is clearly visible that the subject has moved between the frames and thus affected the captured shape.

After applying the rotation and translation, the euclidean distance between each point of the nth and the same point in the following frame was calculated. This distance represents the movement of the subject between 2 frames. Finally, the absolute value of the calculated distances was summed up over all frames. This distance represents the total movement of the subject during the scan. Because of technical issues during rendering of the 4D-scan frames, which resulted in false shape of the subjects' feet, these areas were excluded from the analysis (see Figure 6).

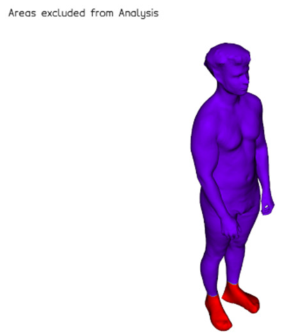

Figure 6 Areas excluded from analysis. The feet (red) were rendered badly due to technical issues and were therefore excluded from both alignment matrix calculation and movement distance calculation.

To compare the results between both scanners, the first frame of the 4D-scan and the resulting mesh of the turntable scanner were aligned on each other using their bounding boxes (see Figure 7).

Figure 7 Mesh comparison. Left: First frame of the 4D-scan; Middle: Mesh produced with the turntable scanner; Right: First 4D-scan frame and mesh from turntable scanner aligned by bounding box and superimposed onto each other.

At preselected heights, the circumference of both meshes was obtained by slicing the meshes parallel to the floor plane and calculating the circumference of both 2D-shapes (see Figure 8).

Figure 8 Basic body measurement comparison. Left: First 4D-scanner frame with slices (darker blue); Middle: Turntable scanner frame with slices (darker green), Right: Slices superimposed onto each other.

4. Results

The total movement of each point is shown in Figure 9. It is clear that the subject was in movement during the scan. While some areas (hip, shoulders) were moved very little, others experienced a total movement of up to 2 cm.

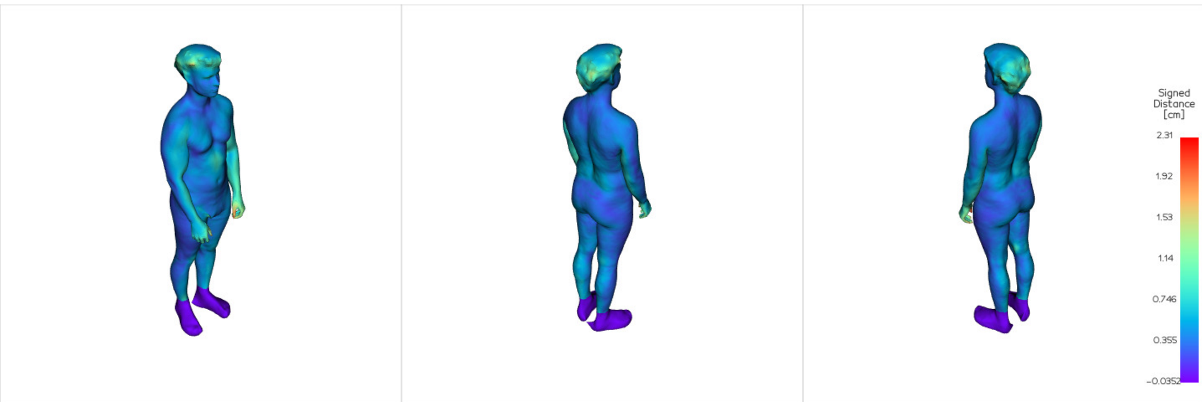

Figure 9 Total Movement of the subject. The colors indicate how much movement of the subject itself took place at each point.

Table 1 shows selected body measurements (slice circumferences) at selected heights. The shoulders remained relatively still, and there is little difference between the measurements obtained by the 4D-scanner and the turntable scanner. In contrast, the calves show a total movement of up to 1 cm. The difference in measurement between the 4D-scanner and the turntable scanner is also higher at the calves.

Table 1 Selected body measurements (slice circumference at given height) taken from the 4D-scan and the turntable-scan

Height [cm]	Measurement	4D-scan [cm]	turntable-scan [cm]	Difference [cm]
140.0	Shoulder	115.91	115.65	0.27
40.0	Upper calf (left)	37.52	38.43	-0.91
40.0	Upper calf (right)	37.44	38.36	-0.92

5. Discussion

It is clear, that the subject moved during the scanning procedure. The belly likely moved because the subject was breathing. The calves likely moved because the subject had to balance itself on the moving turntable. The "movement" of the hair is very likely to be a result of difficulties when capturing hair with 3D-scanning and can be ignored. The arms moved the most during the scan. This is also at least partially likely to be caused by balancing.

The movement caused differences in measurement between the 4D-scan and the turntable-scan. As no ground truth was established, it is difficult to judge which measurement is closer to reality. Further measurements should include a manually taken measure to verify the scanning results. If the data is correct, the body measurements obtained from the turntable scan can differ from the measurements of the measurements obtained from the 4D scan in orders of magnitude up to 1 cm. For ordinary made-to-measure garments and virtual fitting solutions alike, this order of magnitude can be considered acceptable as a tradeoff between price (of the scan) and quality. However, it is difficult to generalize these results. Further scans with more subjects need to be carries out to get a better understanding of how the subjects behave during the scan and how their movement affects the turntable scan.

Disclosure

Dzmitry Komar is the co-founder of Scaneca GmbH, the manufacturer of the 3D-turntable-scanner. He has financial interest in the results of the analysis. He was involved in preparing the experiment and the analysis, but did not directly take part in the evaluation of the data.

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