Report: Evaluation of a Body Scanner

Maker, scanner type, and model number of the evaluated body scanner	I-Ware Laboratory Foot scanner INFOOT 2 / IFU2-S-01
Place of measurement	I-Ware Laboratory
Date of measurement	2020/02/29
Measured by	Kozo Kimura, I-Ware Laboratory
Evaluated by	Makiko Kouchi, Emeritus Researcher National Institute of Advanced Industrial Science and Technology, Artificial Intelligence Research Center Human Informatics Research Institute
Date of report (English version)	2020/03/26

1. Evaluation Protocol

The following protocol follows ISO 20685-2:2015 Ergonomics — 3-D scanning methodologies for internationally compatible anthropometric databases — Part 2: Evaluation protocol of surface shape and repeatability of relative landmark positions.

1-1. Aftefact

The aftefact used for the evaluation is a hollow steel ball, with the surface blasted and treated with TiN (Figure 1). It was calibrated in National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology, using CMM in order to give the “true” value.

Figure 1. Test object (ball, Ø ≈120 mm)

1-2. Locations to measure the artefact

Four locations shown in Figure 2 are used. In determining these locations, we assumed that the size of scanning volume is about 350 (antero-posterior direction) x 150 (lateral direction) x 200 (height) [mm].

Place the ball at each location so that the center of the ball is located at each target position (Figure 2). When more than half of the ball is outside the scanning volume at a location, change the measurement location (height etc.) closer to the center of the scanning volume, and describe the changed position in Sheet-1 as a comment following a file name.

The accuracy of the ball placement is as follows:

(1) height: center of the ball is within ±10 mm of the target position

(2) location in a horizontal plane: center of the ball is within ±10 mm of the target position

Placement of the ball is not very accurate because measurement results are NOT used for calibration, and it is difficult place a ball in an exact position in a space.

You can also measure the ball at locations other than the above 4 locations. When there are added location, write these locations in Sheet-1.

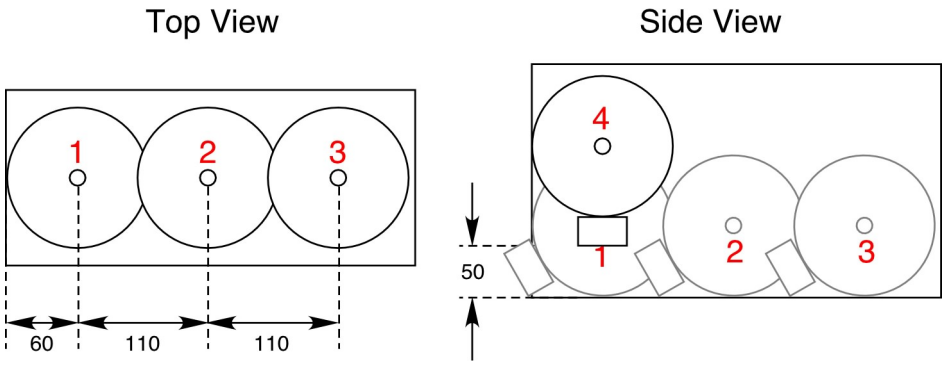

Figure 2. Locations of measurement of the ball by a foot scanner (unit: mm)

1-3. Coordinate system

Obtained data should be described using the coordinate system similar to that described in ISO 20685-2. The standing surface is the X-Y plane, anterior direction is X-axis positive and top direction is Z-axis positive. For the right foot, medial direction is Y-axis positive. When the actual coordinate system is different from the recommended coordinate system, describe the coordinate system in Sheet-1.

When the coordinate system shown in Figure 3 is used, coordinates of the center of the ball at each location in Figure 2 should be approximately as follows (unit: mm):

Location	x	y	z
#1	60,	0,	60
#2	170,	0,	60
#3	280,	0,	60
#4	60,	0,	140

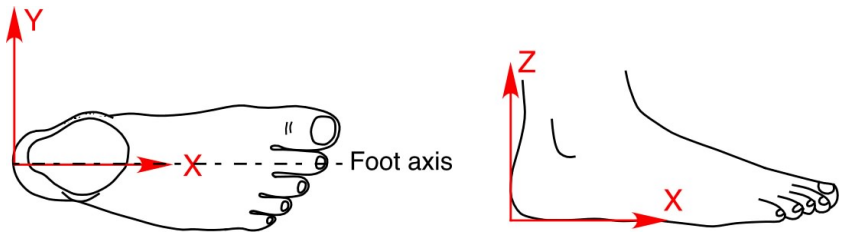

Figure 3. Coordinate system for the foot.

1-4. Procedure of experiment

1) Measure the ball at each location specified in Figure 2. Measurement conditions should be the same with usual human body scanning.
2) Change the coordinate system as specified in Figure 3. If this is difficult, specify the used coordinate system in Sheet-1.
3) Save the scan data measured at each location. Preferred data format is tab delimited text format. If this is impossible, use one of the following formats: Wavefront OBJ, STL, or VRML. Describe which format is used in Sheet-1.

1-5. Procedure to calculate quality parameters

This part will be done in National Institute of Advanced Industrial Science and Technology.

1) Import the point cloud data to Geomagic studio, and remove data points that do not belong to the ball. Data points far away from the ball can also be removed. Save the data in tab-delimited text format.
2) Calculate coordinates of the center of the best-fit sphere (C in Figure 4, right) using software lsmSphre-E as well as the distance from each data point to the center of the best-fit sphere (r_i in Figure 4, right). Save these data in text format.
3) Calculate the following three indicators.

3-1) Error of diameter measurement (P_S)

P_s is calculated by subtracting the true diameter (given by CMM) from the diameter of the best-fit sphere ($d_{calculated}$ in Figure 4, left).

3-2) Spherical form dispersion value (90%)

This is the radial thickness of the shell (shadowed area in Figure 4, right) that contains 90% of measured data points, and calculated by subtracting 5 percentile value of r_i from95 percentile value of r_i.

3-3) Standard deviation of the distance from each data point to the center of the best-fit sphere

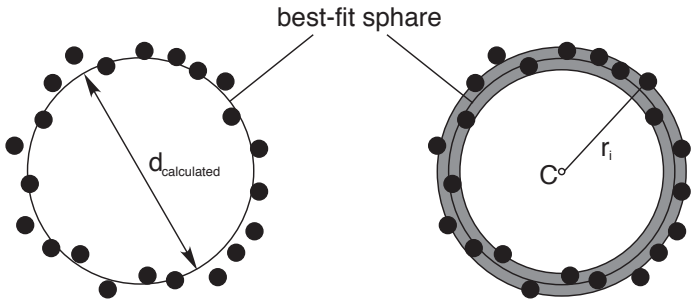

Figure 4. Measured data points, best-fit sphere, and spherical form dispersion value.

C: center of the best-fit sphere

$d_{calculated}$: diameter of the best-fit sphere

r_i: radial distance of the measured data point from the center of the best-fit sphere

shared area: shell including a certain percent of the measured data points.

1-6. Others

Suggestions on unnecessary locations or other necessary locations should be described in Sheet-1.

2. Experiment

Evaluation of a foot scanner
Sheet-1: Measurement of ball

Institute	I-Ware Laboratory Co. Ltd.
Contact	Kozo Kimura 1-10-9 Mino
Date of measurement	2020/02/29
Place of measurement	I-Ware Laboratory Co. Ltd.

Scanner maker	I-Ware Laboratory Co. Ltd.
Model name and model number	INFOOT 2 / IFU2-S-01

1. File name for ball scans

Location #	Location in the horizontal plane	Height (center of the ball)	File name (comment)
1	Base position	60 mm	Ball 1-202002291538r.fbd
2	110 mm anterior	60 mm	Ball 2-202002291543r.fbd
3	210 mm anterior	60 mm	Ball 3-202002291550r.fbd
4	Base position	85 mm	Ball 4-202002291558r.fbd, lower than the recommended position by 5 mm

the size of scanning volume is 330 (antero-posterior direction) x 195 (lateral direction) x 150 (height) [mm]

2. Coordinate system

	Preferred coordinate system	Actual coordinate system
Horizontal plane	X-Y plane	X-Y plane
Anterior direction	X+	X+
Left direction (medial for the right foot, lateral for the left foot)	Y+	Y+
Upper direction	Z+	Z+

3. Unit of measurement	mm

4. File format ~~(select one)~~	FBD (Binary)

5. Recommended scan locations of the ball other than those shown in Figure 2

1
2

3. Evaluation results

Data in FBD format (scanner specific format) was converted into csv format by using file converter software provided by I-Ware Laboratory, before further processing.

Calculated quality parameters are shown in Table 3. Error of diameter measurement was smaller than 0.2 mm in all locations. Spherical form dispersion value (90%) was smaller than 0.5 mm in all locations.

Example of measured sphere at location #2 is shown in Figure 5.

Table 3. Calculated quality parameters (unit: mm)

Location #	Diameter of best-fit sphere	Error of diameter measurement	Spherical form dispersion value (90%)	Standard deviation of radius
1	120.00	-0.01	0.42	0.13
2	119.88	-0.13	0.43	0.14
3	119.88	-0.13	0.43	0.14
4	119.94	-0.07	0.50	0.15

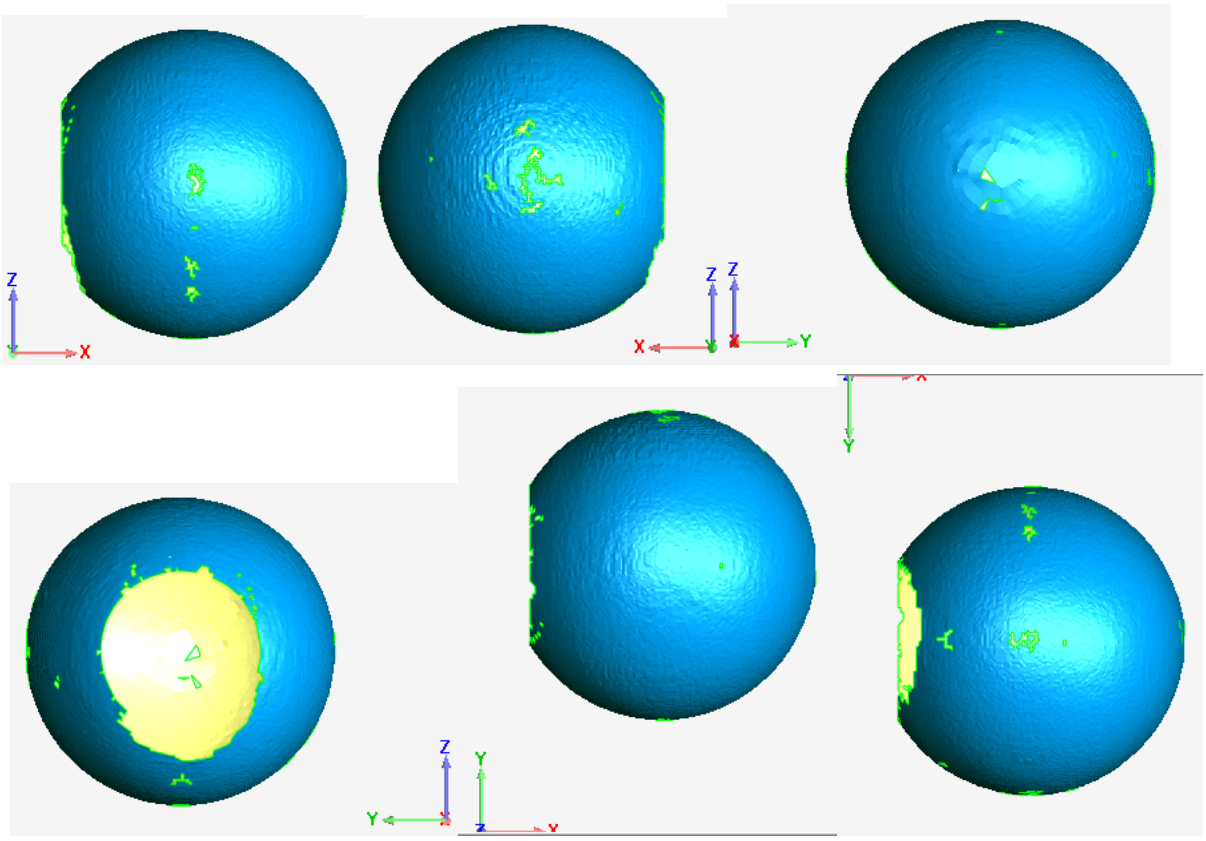

Figure 5. Example of measured sphere at location #2. Data points not belonging to the sphere were manually removed in National Institute of Advanced Industrial Science and Technology.
Top from left: Y-up, Y-down, X-up (top view of the sphere).
Bottom from left: X-down (bottom view of the sphere), Z-up, Z-down