Lost in Translation? Coping with Multiple Scanner Vendors in a Commercial Environment

David B. STEFAN[1], David A. GILBERT[2]
[1] Novaptus Systems Inc., Chesapeake, VA, USA;
[2] The Hague Plastic and Cosmetic Surgery Center, Norfolk, VA, USA

DOI: 10.15221/15.286 http://dx.doi.org/10.15221/15.286

1. Introduction

Changes in scanning technology and the emergence of additional scanner providers are, on the whole, a healthy sign for the industry. It gives users of scanning technology the choice of vendors, and minimizes the possibilities of becoming captive to a particular scanner manufacturer. However, with choice comes challenges in integrating a new scanner vendor into the existing production scanner network. Each vendor has their own measurement software with specific capabilities and it is not reasonable to operate multiple software measurement platforms in a production environment. By using a data modeling program that accepts multiple 3D formats, one can convert the various vendor scanner outputs into a common file format. A data utility program then converts these files to a format to be measured and processed on a commercial basis. In all conversions there are distortions. Quantifying this distortion is possible, but at best it can only be considered to be within an estimation range. The question is whether this distortion during the conversion process is significant.

The answer to this question, in part, depends on the particular scanning application. This network of scanners are used to document the measurements of preoperative morbidly obese individuals prior to, and after weight loss surgery. The morbidly obese are difficult to measure due to their unusual physical shapes. Their bodies undergo significant change as they experience massive weight loss. For the most part, accurate circumferential measurements are not as important as consistent measurement locations in order to document gross circumferential measurement changes.

However, if the scanning application mandates accurate circumferential measurements it would appear to be better served by using the software measurement package provided by the scanner manufacturer rather than converting the scan to another 3D format to be measured by another scanner manufacturer's measurement software.

2. Methods

The scanners in the network are not located near each other. It was not reasonable to ask a morbidly obese individual to get scanned at multiple locations, and even if that was possible the comparisons to be made between individual scanner measurements on a morbidly obese body would have variations beyond that of an individual that has a "typical" body shape.

For this reason, the author selected himself and his spouse as the subjects that were scanned in this paper.

The existing network consists of 3D booth type scanners from Sizestream and TC2. The booth scanners from TC2 are KX-16 and NX-16 models. Both the Sizestream and TC2 KX-16 scanners use near-field infrared lasers. As part of a commercial process, TC2 software is utilized to process the 3D body models from all scanners, including the Sizestream. To include body scans from Sizestream, two additional programs are used. The first imports the .obj file from the Sizestream scanner and subdivides the points comprising the .obj to create a denser body mesh. This file is then saved with a .wrl file extension. The TC2 Data Converter Utility then converts this .wrl file to a .bin format that can be opened within the TC2 KX-16 software measurement program.

Scans from the NX-16, which uses white light technology, need a TC2 utility program to convert the NX-16 .rbd file to the KX-16-type .rbd file that the measurement software program requires. Binary files from the NX-16 can be loaded directly and converted to an .rbd file within the TC2 measurement software without the need of this conversion utility.

Multiple scans were taken of the same individuals using the Sizestream scanner. Multiple scans were taken of the same individuals using a TC2 NX-16 scanner.

Two separate measurement systems were used to measure the scans acquired by the Sizestream scanner: The measurements provided by the Sizestream measurement software, and the measurements provided by the KX-16 measurement software after the Sizestream scan was converted to KX-16 .binary format.

This provides a comparison between using the Sizestream measurement software and the TC2 KX-16 measurement software.

The scans acquired by the NX-16 were processed as binary files within the KX-16 software, bypassing the need for the KX-16 conversion utility,

The measurement comparison matrix is shown in Table 1.

Measurement Format	Sizestream .obj	Sizestream converted to TC2 KX-16 .rbd	TC2 KX-16 .rbd from NX-16 .binary
Male	x	x	x
Female	x	x	x

Table 1. Measurement Comparison Matrix

Three scans of each subject were successively taken using the Sizestream scanner. Three scans were taken using the TC2 NX-16 scanner.

A common extraction profile was created within each software measurement platform. Table 2 compares the extraction profiles and nomenclature used for TC2 and Sizestream.

The template produces circumferential measurement information only. This is the template that is applied in commercial practice to document the preoperative and postoperative circumferential measurements of individuals who underwent a weight loss surgical procedure.

In actual practice, another template is also applied to 3D body models created by the scanner that extracts torso volume, torso surface area, bulk volume and torso slices. These multidimensional extractions were not part of this straightforward comparison analysis.

TC2 Measurements, Inc	Sizestream Measurements, Inches
Neck_Full	Neck Circumference
Bust_Full	Bust Girth with Drop Tape
Right_Biceps	Bicep Circum Right
Right_Elbow	Elbow Circum Tape Right
Right_Forearm	Forearm Circum Right
Left_Biceps	Bicep Circum Left
Left_Elbow	Elbow Circum Tape Left
Left_Forearm	Forearm Circum Left
Waist_Full	Waist Circumference
Hips_Full	Hips Circumference
Seat_Full	Seat Circumference
Abdomen_Full	Abdomen Circumference
Thigh_Left	Thigh Circum Left
Thigh_Right	Thigh Circum Right
Calf_Left	Calf Circum Left
Calf_Right	Calf Circum Right
Knee_Left	Knee Circum Left
Knee_Right	Knee Circum Right

Table 2. Measurement Extraction Profile Comparisons between TC2 and Sizestream

The measurement results for the male and female subjects were tabulated and compared. The first comparison was for the successive scans acquired by the individual machines as measured by the manufacturer's software measurement package. This gives a fair picture of the circumferential measurement consistency between successive scans on the same scanning platform.

The average of the measurements of the three sequential scans acquired by each machine was calculated, as was its standard deviation.

The Sizestream scans were then converted to a format that produced TC2 binary files. These were loaded into the KX 16 measurement software, converted to a measurable .rbd format and the TC2 measurement template was applied.

It must be noted that both the Sizestream and TC2 NX-16 were calibrated per manufacturer's procedures prior to acquiring the scans utilized in this analysis.

Both subjects attempted to be scanned in the same position during the scan acquisition process.

3. Results

Table 3 displays the measurement results from three sequential scans for a male as acquired and measured by the Sizestream scanner and the Sizestream measurement software.

Sizestream Measurements, Inches	Scan 1	Scan2	Scan 3	Average	Std Dev
Neck Circumference	19.23	17.93	18.77	18.64	0.66
Bust Girth with Drop Tape	41.31	41.42	41.32	41.35	0.06
Bicep Circum Right	13.92	13.93	13.96	13.94	0.02
Elbow Circum Tape Right	11.60	11.76	12.18	11.85	0.30
Forearm Circum Right	11.82	11.90	11.90	11.87	0.05
Bicep Circum Left	13.61	13.83	13.33	13.59	0.25
Elbow Circum Tape Left	11.60	12.17	11.91	11.89	0.29
Forearm Circum Left	11.60	11.75	11.61	11.65	0.08
Waist Circumference	38.30	38.36	38.23	38.30	0.07
Hips Circumference	39.35	39.43	39.21	39.33	0.11
Seat Circumference	38.65	38.82	38.68	38.72	0.09
Abdomen Circumference	38.59	38.69	38.60	38.63	0.06
Thigh Circum Left	21.48	21.65	21.32	21.48	0.17
Thigh Circum Right	21.58	21.66	21.26	21.50	0.21
Calf Circum Left	14.92	14.92	14.79	14.88	0.08
Calf Circum Right	15.15	15.15	15.07	15.12	0.05
Knee Circum Left	15.08	15.36	14.97	15.14	0.20
Knee Circum Right	14.84	15.00	14.71	14.85	0.15

Table 3. Three Successive Scans of a Male Subject using the Sizestream Scanner and Sizestream Measurement Software

Inspection of Table 3 indicates some of the issues common with all 3D booth scanners in that the subject tried to stand in the same position as each scan was acquired, but inevitably, the position of the arms differed slightly between each scan. This resulted in different circumferential arm measurements, though the "Bicep Circumference Right" scan was consistent throughout the series. The neck measurements were quite different for each scan.

Table 4 displays the measurement results from the three sequential scans for a male as acquired by the TC2 NX-16 scanner and the TC2 KX-16 measurement software. Note that the binary file from the NX-16 was used to produce the .rbd file within the KX-16 software, bypassing the need for using the TC2 "RBDConverter" utility.

TC2 Measurements, Inches	Scan 1	Scan 2	Scan 3	Average	Std Dev
Neck_Full	17.99	17.46	17.57	17.67	0.28
Bust_Full	41.72	41.60	41.70	41.67	0.06
Right_Biceps	13.92	13.32	13.58	13.61	0.30
Right_Elbow	11.03	10.79	10.99	10.94	0.13
Right_Forearm	11.80	11.50	11.58	11.63	0.15
Left_Biceps	13.23	13.50	13.66	13.46	0.22
Left_Elbow	10.79	10.67	10.63	10.69	0.08
Left_Forearm	11.24	11.30	11.20	11.24	0.05
Waist_Full	38.52	38.64	38.55	38.57	0.06
Hips_Full	39.49	39.46	39.70	39.55	0.13
Seat_Full	38.82	38.91	38.93	38.89	0.06
Abdomen_Full	38.99	39.09	39.08	39.05	0.06
Thigh_Left	22.25	22.31	22.56	22.37	0.16
Thigh_Right	22.20	22.20	22.20	22.20	0.00
Calf_Left	15.06	15.15	15.04	15.08	0.06
Calf_Right	15.30	15.15	15.44	15.30	0.14
Knee_Left	15.72	15.91	15.83	15.82	0.09
Knee_Right	15.62	15.49	15.81	15.64	0.16

Table 4. Three Successive Scans of a Male Subject using the TC2 NX-16 Scanner and TC2 KX-16 Measurement Software

Table 4 shows a similar trend with the NX-16 scanner, particular for the circumferential arm measurements.

Table 5 depicts a “straight up” comparison with the measurement averages produced by the Sizestream scanner and the KX-16 scanner.

		Sizestream Average	TC2 NX-16 Average		Sizestream	TC2 NX-16
		Average	Average	Difference	STD DEV	STD DEV
Sizestream Measurements, Inches	TC2 NX 16					
Neck Circumference	Neck_Full	18.64	17.67	-0.97	0.66	0.28
Bust Girth with Drop Tape	Bust_Full	41.35	41.67	0.32	0.06	0.06
Bicep Circum Right	Right_Biceps	13.94	13.61	-0.33	0.02	0.30
Elbow Circum Tape Right	Right_Elbow	11.85	10.94	-0.91	0.30	0.13
Forearm Circum Right	Right_Forearm	11.87	11.63	-0.24	0.05	0.15
Bicep Circum Left	Left_Biceps	13.59	13.46	-0.13	0.25	0.22
Elbow Circum Tape Left	Left_Elbow	11.89	10.69	-1.20	0.29	0.08
Forearm Circum Left	Left_Forearm	11.65	11.24	-0.41	0.08	0.05
Waist Circumference	Waist_Full	38.30	38.57	0.28	0.07	0.06
Hips Circumference	Hips_Full	39.33	39.55	0.22	0.11	0.13
Seat Circumference	Seat_Full	38.72	38.89	0.17	0.09	0.06
Abdomen Circumference	Abdomen_Full	38.63	39.05	0.43	0.06	0.06
Thigh Circum Left	Thigh_Left	21.48	22.37	0.89	0.17	0.16
Thigh Circum Right	Thigh_Right	21.50	22.20	0.70	0.21	0.00
Calf Circum Left	Calf_Left	14.88	15.08	0.21	0.08	0.06
Calf Circum Right	Calf_Right	15.12	15.30	0.18	0.05	0.14
Knee Circum Left	Knee_Left	15.14	15.82	0.69	0.20	0.09
Knee Circum Right	Knee_Right	14.85	15.64	0.79	0.15	0.16

Table 5. A “Straight Up” Comparison of Measurements between Scans acquire by Sizestream and TC2 NX-16

Inspection of the “Difference” column in Table 5 depicts the variation between the average measurement values created by the Sizestream measurement software and the average measurement values created by the TC2 KX-16 measurement software that used scan images acquired by an NX-16 scanner. There are, of course, some differences. An interesting observation is that there appears to be no real pattern as to the difference measurement outcomes between the two scan sets. That is, one cannot say that either scanner measurement software overestimates or underestimates the whole SET of measurements applied to the 3D body models.

Table 6 displays the measurements of each Sizestream scan converted to TC2 binary format using the conversion process outlined earlier and measured by the measurement extraction profile within the TC2 KX-16 measurement software.

Measurements, Inches	Scan 1	Scan 2	Scan 3	Average	STD DEV
Neck_Full	17.60	17.55	17.69	17.62	0.07
Bust_Full	41.79	41.65	41.43	41.62	0.18
Right_Biceps	13.62	13.61	13.57	13.60	0.03
Right_Elbow	11.29	11.13	11.28	11.23	0.09
Right_Forearm	11.46	11.50	11.53	11.50	0.04
Left_Biceps	13.09	13.22	12.91	13.07	0.15
Left_Elbow	10.97	11.23	11.54	11.25	0.29
Left_Forearm	11.19	11.28	11.33	11.26	0.07
Waist_Full	38.27	38.34	38.16	38.26	0.09
Hips_Full	39.23	39.31	39.06	39.20	0.13
Seat_Full	38.63	38.74	38.67	38.68	0.06
Abdomen_Full	38.74	38.74	38.65	38.71	0.05
Thigh_Left	20.09	20.06	19.66	19.94	0.24
Thigh_Right	20.07	20.16	19.74	19.99	0.22
Calf_Left	14.63	14.73	14.62	14.66	0.06
Calf_Right	15.04	15.03	14.93	15.00	0.06
Knee_Left	14.57	14.69	14.41	14.56	0.14
Knee_Right	14.39	14.43	14.19	14.34	0.13

Table 6. Three Successive Scans of a Male Subject using the Sizestream Scanner converted to TC2 Format and Measured with TC2 Measurement Software

Table 7 displays the average measurements for the male scans acquired from the Sizestream scanner using Sizestream measurement software, the average measurements for the male scans acquired from the Sizestream scanner converted to TC2 binary format, and the average measurements of the male scans acquired by the TC2 NX-16 scanner as measured by the TC2 KX-16 measurement software.

	Sizestream Average	TC2 NX-16 Average	Sizestream - TC2	Sizestream to TC2 Convert	Sizestream to TC2 Convert	Sizestream to TC2 Convert
	Average	Average	Difference	Average	Difference from Sizestream	Difference from TC2 Scans
Meas, Inches						
Neck_Full	18.64	17.67	-0.97	17.62	-1.03	-0.06
Bust_Full	41.35	41.67	0.32	41.62	0.27	-0.05
Right_Biceps	13.94	13.61	-0.33	13.60	-0.34	-0.01
Right_Elbow	11.85	10.94	-0.91	11.23	-0.61	0.30
Right_Forearm	11.87	11.63	-0.24	11.50	-0.37	-0.13
Left_Biceps	13.59	13.46	-0.13	13.07	-0.52	-0.39
Left_Elbow	11.89	10.69	-1.20	11.25	-0.65	0.55
Left_Forearm	11.65	11.24	-0.41	11.26	-0.39	0.02
Waist_Full	38.30	38.57	0.28	38.26	-0.04	-0.32
Hips_Full	39.33	39.55	0.22	39.20	-0.13	-0.35
Seat_Full	38.72	38.89	0.17	38.68	-0.04	-0.21
Abdomen_Full	38.63	39.05	0.43	38.71	0.08	-0.34
Thigh_Left	21.48	22.37	0.89	20.93	-0.55	-1.44
Thigh_Right	21.50	22.20	0.70	20.98	-0.52	-1.22
Calf_Left	14.88	15.08	0.21	14.66	-0.22	-0.42
Calf_Right	15.12	15.30	0.18	15.00	-0.12	-0.30
Knee_Left	15.14	15.82	0.69	14.56	-0.58	-1.26
Knee_Right	14.85	15.64	0.79	14.34	-0.51	-1.30

Table 7. Male Subject Average Measurement Comparisons for Sizestream Scans, TC2 Scans and Sizestream Scans converted to TC2 Format

Table 7 gives us a good snapshot of the three measurement averages for the male subject. Not only are there differences between the measurements retrieved by individual scanners and their respective measurement software packages, there are differences between scans acquired by one scanner and converted to a format that can be measured by another scanner manufacturer's software.

Table 8 contains similar information as in Table 7, but for the female subject.

	Sizestream Average	TC2 NX-16 Average	Sizestream - TC2	Sizestream to TC2 Convert	Sizestream to TC2 Convert	Sizestream to TC2 Convert
	Average	Average	Difference	Average	Difference from Sizestream	Difference from TC2 Scans
Meas, Inches						
Neck_Full	15.26	15.50	0.24	15.44	0.18	-0.06
Bust_Full	39.40	39.95	0.55	39.86	0.46	-0.10
Right_Biceps	11.40	12.72	1.33	12.28	0.88	-0.44
Right_Elbow	10.94	10.11	-0.83	10.57	-0.37	0.46
Right_Forearm	10.41	10.07	-0.34	10.24	-0.17	0.17
Left_Biceps	12.11	12.26	0.15	11.81	-0.30	-0.45
Left_Elbow	10.98	10.63	-0.35	10.49	-0.49	-0.14
Left_Forearm	10.33	10.50	0.17	9.95	-0.38	-0.55
Waist_Full	36.10	35.55	-0.55	35.77	-0.33	0.22
Hips_Full	38.76	38.80	0.04	38.65	-0.11	-0.15
Seat_Full	38.54	38.76	0.22	38.54	0.00	-0.22
Abdomen_Full	37.23	35.65	-1.58	36.20	-1.03	0.55
Thigh_Left	20.79	21.05	0.27	20.86	0.07	-0.19
Thigh_Right	20.36	20.43	0.07	20.38	0.02	-0.05
Calf_Left	13.69	13.89	0.20	13.56	-0.13	-0.34
Calf_Right	13.37	13.61	0.25	13.24	-0.13	-0.37
Knee_Left	14.03	13.77	-0.25	13.84	-0.18	0.07
Knee_Right	13.64	13.21	-0.43	13.44	-0.20	0.23

Table 8. Female Subject Average Measurement Comparisons for Sizestream Scans, TC2 Scans and Sizestream Scans converted to TC2 Format

The measurement changes documented in Table 8 show differences between the scans and their various measuring programs, but their differences do not reflect the same pattern as for the male subject in Table 7.

4. Discussion

This has been an exercise involving two booth type 3D scanners, one from Sizestream and the other from TC2, their respective software measurement packages, and converting Sizestream scans to a TC2 binary format for use in the TC2 KX-16 software measurement package.

The subjects were scanned multiple times in both scanners. The results indicate differences between the two software measurement packages. This is true for measuring successive scans acquired by the same machine. Of course, it is always difficult to remain in the exact scanning position for multiple scan acquisitions. Arm positions inevitably changes, and so perhaps, does the angle of head elevation. These changes in positions directly affect the location of the measurement landmarks and hence the particular circumferential measurement values.

There are also similar measurement differences between scans from the Sizestream scanner converted to the TC2 binary format and measured with the TC2 KX-16 measurement software.

The question then is: Does it even matter?

Like most any question, the answer is: “It depends.”

The commercial network in use today is set up to scan preoperative morbidly obese individuals that will be undergoing a weight loss surgical procedure. The best that can be hoped for given the size of their bodies are gross measurements based on fairly consistent landmarks. It is not uncommon to manually move landmarks within the software measurement package to achieve this.

These individuals return for postoperative periodic postoperative visits and are typically scanned at 3 month, 6 month and 1 year after surgery intervals. Their bodies experience massive weight loss during the first 3 months, with weight loss continuing to occur thereafter at a slower rate, albeit still significant. These relative measurement changes appear to be something that both scanners document well.

The scanners are thus used to track gross circumferential measurement changes that accompany weight loss surgery. Specific circumferential measurement accuracy is not as important as the relative change in the measurements that are extracted, recorded and presented to the individual.

However, other applications might not have the luxury of comparing such dramatic measurement changes over time. Here is where one needs to be more careful.

A business that scans thin and shapely bodies in order to construct made-to-fit swimwear such as bikinis or briefs might have to think hard about using two separate scanners and two separate measurement software packages. The measurement discrepancy between the two manufacturers may be too great for this application.

There is one area in this analysis of two separate scanner manufacturers and two separate measurement software packages that was not investigated. It is becoming more and more important as new ways to categorize obesity are being researched.

This is the area of volume and surface area calculations, including torso volume and surface area. At present, the interest has been in tracking and documenting circumferential measurement changes as an individual undergoes massive weight loss. It is argued here that for this application, relative measurement changes are more important than accurate measurements, hence two different scanners and one measurement software package, including conversion utilities can be implemented with a fair degree of confidence.

To calculate new multidimensional obesity indicators that use torso volume and torso surface area will require more consistency than what has been found for circumferential measurements. Circumferential measurements are generally created by locating fairly complex landmarks on the 3D body model. Slight differences in landmark locations as a result of changes in the scanning position will result in inconsistent circumferential measurements, even between two successive scans from the same scanner manufacturer. This is understood.

Fortunately, multidimensional information such as torso volume and torso height require only two landmarks: “Back of Neck” and “Crotchpoint.” If these are accurately located and the dimensions of the torso, including the shoulders are similar between the 3D body models created by separate scanner manufacturers, there could be multidimensional consistency across scanning platforms.

It is important that 3D body models acquired by 3D booth scanner manufacturers be consistent and as interchangeable as possible. This exercise has showed that at least for the current application, by and large they are.

3D booth scanners and their measurement software packages need to act as reference platforms as new, more mobile 3D scanning technologies begin to proliferate.