The verification of measurement extracted from 3D
(three-dimensional) scanned against manual data

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ABSTRACT
The purpose of this study is to investigate the validity of scanned data rendered from scanner in China Textile Institute. Two approaches were used to verify the validity: the first one was stability test, this test is to measure the human body movement during two consecutive scans; the other was the repeatability test, this test was to study the repeatability of extracted measurements from the different scan data of a same subject. The results were also compared with manual results to study the discrepancy between scanned data and manual data. Twenty-one measurements including circumferences and body surface lengths were selected as critical measurements. Ten subjects (5 males and 5 females) were recruited in both tests. The result of stability test indicates that the body variation within two scans is within 15 mm. The mean standard deviation in repeatability test was 7.63 mm, it is slightly higher than ISO requirement but meet the acceptance criteria of tailors. The mean difference between extracted data and manual data reaches 35.1 mm, it just barely meets the grading criteria. This difference may be due to the different definition of measurements.

Keywords: 3D body scanning, Anthropometry, Body measurements

1. Introduction
The advance of 3D whole body scanning technology has provides a powerful means for garment industry on mass production as well as mass customization. Traditionally, manual collected 1D (one dimensional) body measurements are used on pattern making and sizing criteria for ready-to-wear clothing. However, this requires lots of manpower and time, and the application of 1D data is limited. The 3D scanning technology provides fast way of collecting human body data as well as measurements. These measurements could be used in
size database for ready-to-wear clothing as well as rendering made-to-measure pattern in short
time. The 3D data rendered by scanner also provides more information on 2D shapes and
3D body forms. This extends the applications to virtual try-on and pattern development.

China Textile Institute (CTI) has been conducting 3 dimensional (3D) anthropometry studies
over the past three years; the main purpose is to develop the technique in the application of
3D body data for garment industry. A 3D whole body scanner was set up under cooperation
of a Taiwan research institute last year. Before the further studies are conducted, it is
necessary to verify the validity of scanned data.

The 3D whole body scanner is a non-contact method to collect human body dimension.
Sources of error could be introduced in the scanning. Study of Brook-Wavell et al. indicated
that the repeatability was no better than the manual data [1]. Breathing and human body
movements are the two error sources that are common to be observed. It is not easy for
subjects to stand still without involuntary movements and hold breath for a long time.
Besides, the scanning posture is another factor that may affect the result. The scanner
usually requires a standard scanning posture such as straight standing. This may lead to less
precise result if the processing software requires strict scanning posture since people stands
slightly different in someway or another ever time.

Thus, the main focus of this study is to investigate the degree of movement in the 15 sec
scanning time in CTI scanner and the repeatability of extracted measurement from different
scans. The human body variance should be studied to understand the degree of movement
during the scan. Some published data on measurement repeatability such as tailor
acceptance criteria proposed by Bradtmiller et al. [2], ISO 8559 [3] and ANSUR data from
Gordon et al. [4] and commonly grading value are used as reference benchmarking. Two
tests were conducted to verify the results. The first one was the stability of subject during
scanning so that the point data accuracy is guaranteed. The second test was to verify effect
of different postures on the extracted result.

2. Methods

Two experiments were conducted to verify the validity of extracted data. The first
experiment was to test the stability of human body while scanning and the second experiment
was to test the robustness of extracted measurement to postures.
2.1 Experimental design

2.1.1. Stability test

The test was to investigate the degree of human body movement in two consecutive scans. Six body areas were selected as targets: Chest, waist, two wrists and two knees. Six markers were attached onto the following location: mid point of the line connecting two armpits, front waist point, two wrists and two knees. Subjects were asked to stand as still as possible during two scans. Ten subjects, 5 males and 5 females were recruited in the test. The age ranges from 25 to 35 years old. The weight ranges from 45 to 75 kg with mean of 53 kg. The total processing time is about 50 seconds including two scan periods (15 sec each) and the data processing time between two scans. The coordinate of markers was then recorded to determine the movement of body posture.

2.1.2. Repeatability test

The experiment was to investigate the variance from measurements extracted from the different scan data of the same subject. There were two sessions in this experiment. In the first session, scanner was used to scan subject to extracted body measurements. Twenty-one measurements were selected by two experienced tailors (more than 10 years of working experience) in CTI to represent the important measurements for garment making. Table 1 list the 21 selected measurements. Each subject was scanned five times. Subjects were instructed to leave the scanning cabin after each scan and enter again for next scan. This was to prevent subject from keeping same posture every time. The scanned data were then processed by Textile clothing and technology corporation (TC^2) to extract 21 measurements. In the second session, the two experienced tailors measure the 21 measurements on each subject with tape.

Table 1. Twenty-one selected measurements

<table>
<thead>
<tr>
<th>1. FullChest</th>
<th>8. FrontNeckToWaist</th>
<th>15. ArmLength</th>
</tr>
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</table>

Ten subjects (5 males and 5 females) were recruited in this test; five of them were subjects
from first experiments. The age ranges from 20 to 36 years old. The weight ranges from 42 kg to 75 kg with mean 61 kg.

2.2 Data analysis

For the stability test, the deviations between corresponding markers were calculated in distance as well as the difference along three axes. Mean values were determined by marker location for 10 subjects.

For the repeatability test, mean values were derived based on extracted measurements from 5 scans among 10 subjects. One-way ANOVA was used to test if the value extracted from different scanning (ie different postures) were of significant difference for each measurement. The deviations were compared with the present measurement repeatability proposed by ISO 8559, ANSUR data and tailor acceptance criteria (listed in table 2). The two measurements of each tailor’s data were averaged to derive the mean value. Two-way ANOVA and Duncan multiple comparison test were used to test if there were significant difference between the automatic extracted measurements and the two tailors’ results.

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Tailor acceptance criteria</td>
<td>9 mm</td>
</tr>
<tr>
<td>ISO</td>
<td>5 mm</td>
</tr>
<tr>
<td>ANSUR</td>
<td>5-6 mm</td>
</tr>
<tr>
<td>Grading</td>
<td>30 mm</td>
</tr>
</tbody>
</table>

3. Results

3.1 Stability test

The results of stability test indicated that the variation of human body is less than 15 mm in 50 seconds. The mean deviation distance is 10.2 mm with range from 6.7 mm to 13.5 mm. The max variation areas are two wrists (13.5 mm), follows with chest, abdomen and two knees. Except for two wrists, the variation should not affect the measurement much. Figure 1 shows the distance as well as the deviation in three axes respectively. It is noted that the X-axis variation is the greatest among the three-axis variation. It shows that people tends to swing forward and backward (the X axis represent the forward and backward direction).
3.2 Repeatability test

The mean SD (standard deviation) of these five scans among 10 subjects and measurements ranges from 22.05 mm to 2.38 mm with mean equals to 7.63 mm. Figure 2 plot the mean SD of these five scans among 10 subjects for each measurement. It is noted that most of the SDs are smaller than 10 mm while the largest SD located at Arm length. The result of one-way ANOVA shows that there is no significant difference among these measurements (p value > 0.05).
Figure 2. The mean SD distribution of 21 measurements.
The results of comparison between scanned result with two manual results show that the mean differences among 21 measurements are 31.2 mm and 35.2 mm respectively. Figure 3 shows the mean difference between these methods among 21 measurements. The difference is greatest at FrontcrotchLength (100 mm) and the smallest difference is at Collarsize (1 mm). It is also noted that this degree of difference could only barely meet the grading criteria while violate other tighter standards.

Figure 3. The difference among three different methods of measurements.

The result of two-way ANOVA shows that there are significant differences among these three methods: one scan plus two tailors’ results (p value < 0.05). The Duncan multiple comparing test did not reveal any consistent result indicating that one method is significantly different from the other two methods. In other words, two tailors differs in some measurements while scan method differs from tailors in some other measurements.

4. Discussion

The variation of human body in the 15 sec scanning time does not affect the scanned result much. The largest variation occurred at wrist for about 10 mm in 50 sec time, and 15 sec exposure time may greatly reduce the variance. However, a pair of handle will be added to the scanner later to more stabilize the body during scan.

The repeatability test shows that the posture variation is acceptable for measurement extraction. The largest variation occurs on Armlength. There are two reasons that may account for this variance. Firstly, the scan data points at wrists are fewer than that at body, therefore, less data are available for measurement extraction; secondly, the hands moves
greater than any other body parts during the scan which lead to less accuracy result. The other measurements that close to tailor acceptance criteria (10 mm) are Fullcrotch and measurements around chest. The variation in Fullcrotch may be explained by the fact that crotch is a hidden area to scanner so that extrapolations of data is required. The variation in chest area may be due to the breathing. It is not easy to instruct the subject and make sure they hold breath while scanning.

As compared with the other reference value for measurement variation, most of the variance barely meet tailor’s acceptance criteria but fail to meet the more tightly set ANSUR and ISO standard (about 5 mm). It is hoped that implementing the handles could reduce more variance.

The fact that the definitions of measurements are not the same for automatic extraction software and tailors may explain the great difference between scan data and tailor’s data. The greatest difference occurs in the measurement for FrontCrotchLength. This measurement requires identification of two landmarks; Crotch and Front Waist. However, for manual measurement, a bar is used as assistance to identify the contact of crotch point while the automatic extraction could only determine the outside profile. Since the crotch lies almost in the hidden area to scanner, it is not easily to locate the same point as manual measurement does. The determination of waist line is another issue, the way waist in determined differ from tailor to tailor and the determination algorithm of extraction software may not be as same as human being. The fact that great differences also occur in measurements related to waist and crotch (FullCrotchLength, FrontNecktoWaist) supports this reasoning. It is also noted that the difference among tailors are also greater among these measurements. This indicates that this two landmarks are not consistent to every tailors. The large difference in ArmLength may be due to the fact that tailors uses different end point of hand to software since the difference between tailors are very small. The difference for FullChest may be explained by the different location of armpit, since it lays in the border of data clouds and tailors uses rubber band to identify the point. This also explains the difference in AcrossChest.

The results of this study suggest that variance of scanned data is low and the repeatability of extracted measurements is acceptable. However, for further implement of the scanned measurements, it is recommended that certain measurement definition should be revised so that the measurement could be used in pattern making with better fit. It is also suggested two set of definition should be used in the future. The whole set of definitions for scanned data measurement extraction be developed based on geometric definition while the manual measurement be based on traditional definition. This will help the further application in 3D apparel CAD system which could develop 2D pattern directed from 3D human model as well
as 3D clothing model.

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6. Reference


