BODY MEASUREMENT USING 3D HANDHELD SCANNER

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Abstract

Body measurement is the first process that must be encountered before any custom-made compression garment can be designed. The current practice of obtaining the measurement is by traditional methods using tools like measuring tape. However, this method is considered to be time-consuming and usually not accurate. The most popular solution to the problem is by using non-contact measurement. The development of the 3D whole body scanner has made non-contact body measurement become a reality due to its capacity to capture a vast amount of information. However, the cost to buy the whole body scanner is quite expensive. Moreover, their sizes are also bulky which make them less portable. Thus, a handheld body scanner provides a solution to the problem. Despite that, current handheld scanner only provide image and visualization aspect, but not the measurement aspect. This paper reports the development of a method to acquire body data from a 3D handheld scanner. In this new method, the point cloud of a body part was collected using the handheld scanner. Then, the data was transformed into point coordinates. Several processes were developed to filter the number of points to allow for faster processing time and increasing the measurement accuracy. In the first process, only points at specific height/layers are selected. In the second process, the remaining points are rearranged according to their height and angle. In the last process, the number of points is further reduced. In this process, the number of points per layer is limited to 72 points. Results show that the method can be used to determine body measurement.

Keywords: Body measurement, handheld scanner, custom-made garment, non-contact measurement

Introduction

Size and shape measurements for the human body are an important source of information and affect design decisions. Thus, since ancient times, humans have shown a great interest in the study of their body. Hippocrates and Da Vinci are among the famous people for whom that the human body was found to be fascinating. Body measurement is the first process that must be considered before any custom-made garment can be designed. The current practice of obtaining the measurement is by traditional methods using tools like measuring tape. However, this method is considered to be time-consuming and often inaccurate (Istook and Hwang, 2001; Simmons and Istook, 2003; Pargas, Staples, and Davis, 1997).

The most popular solution to the problem is by using non-contact measurement (Simmons and Istook, 2003). Non-contact measurement is a method where body parts are measured without any physical contact with the tools (Hobden, 1998). The development of the 3D body scanner has made non-contact body measurement become a reality due to its capacity to capture a vast amount of information. There are two basic parameters that need to be measured, the circumferences of a body part and the distance between two sections of the body.

Several researchers (Pargas, Staples, and Davis, 1997; Zhong and Xu, 2006; Izadi et al., 2011; Bragança, Carvalho, Xu, Arezes, & Ashdown, 2014) had developed their own 3D body scanners. Besides that, several companies have also developed the technology to extract body measurements from a 3D body model like $[TC]^2$, Voxelan, Telmat, and Cyberware.

The Textile/Clothing Technology Corporation, $[TC]^2$ had developed a software system that could obtain hundreds of automatic measurements from a 3D body model, thus creating custom measurement profiles for automatic measurement. Voxelan also introduced their 3D Measure Workshop software. By just clicking a mouse directly on the 3D body model, measurements could be achieved instantly. The SymcadOptifit system from Telmat and Digisize from Cyberware can also produce body measurements accurately.

However, the prices of the commercially available technologies are very expensive. Moreover, their sizes are also bulky which make them less portable. Thus, researchers, such as Izadi et al. (2011), Jung et al. (2011), Cappelletto, Zanuttigh, and Cortelazzo (2011), and Bragança et al. (2014) have come out with a new type of scanner called 3D handheld scanner. This type of scanners is cheaper and are readily available to be transported to other places, in other words, ease of mobility.

3D handheld scanner

Hand-held scanners create a 3D image through the triangulation mechanism. A laser/ light dot or line is projected onto an object from a hand-held device, and a sensor measures the distance to the surface. Data is collected in relation to an internal coordinate system and therefore to collect data where the scanner is in motion the position of the scanner must be determined. The position can be determined by the scanner using reference features on the surface being scanned or by using an external tracking method. External tracking often takes the form of a laser tracker to provide the sensor position with an integrated camera to determine the orientation of the scanner. Point clouds produced by the 3D scanners can be used directly for visualisation. Currently, there are lots of handheld 3D scanners in the market. Their price is also much lower than the 3D whole body scanner. However, most of the affordable handheld scanners just provide the visualization, without any measurement. Thus, Salleh et al. (2017) proposed a new method to collect body measurement using 3D handheld scanner. However, the proposed method has a major drawback. The scanned data must be transferred to different software for processing. Thus, it increases the production cost and adds further unnecessary time. This research aims to expend the existing method to acquire body data from a handheld scanner. The technology to measure body parts from a 3D body model is vital for the development of customized garment and products for athletes. The technology will enable a manufacturer to accumulate data of an athlete and obtain its measurements from the body model. The information can increase the manufacturer's capabilities of fulfilling the fitting requirements of the athlete. It can also avoid inconsistencies and difficulty caused by manual measurement.

Methodology

Figure 1 shows the steps to acquire body measurement used in the research.

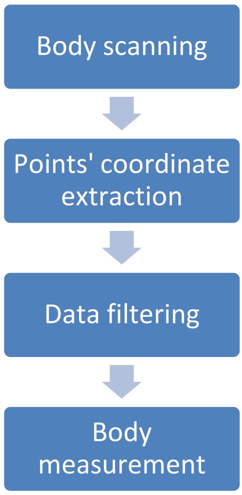


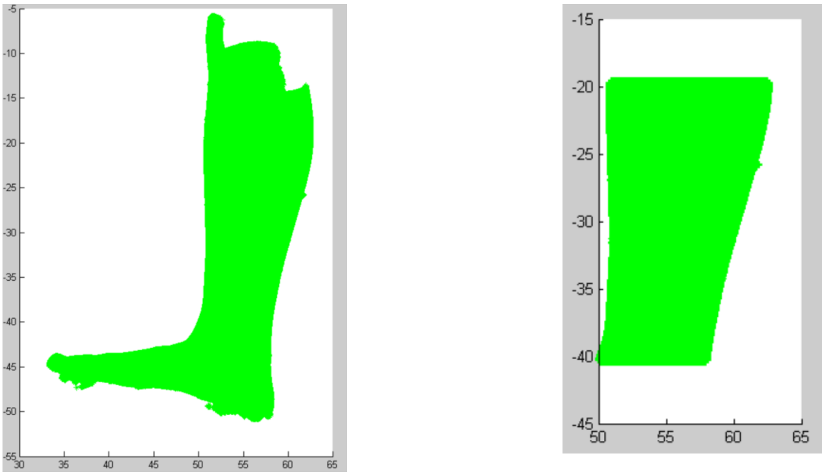
Figure 1: Flowchart of methodology used in the research

A. Body scanning

For this research, handheld Sense 3D scanner was used for body data acquisition. The left leg of a subject was scanned using the equipment to capture the cloud point data.

B. Points' coordinate extraction

The data was processed in Matlab software for 3D modelling (refer Figure 2a). The number of cloud point data in the figure is very large, containing more than 1.4 million points. The large number of points will make data processing time to become longer. Thus this research focused on the area between -40 to -20 cm which contain just 622,734 points for measurement (refer Figure 2b). Even though the number of data is half from the real data, the number is still substantial. Therefore, in order to overcome the problem, the cloud data needs to be filtered to reduce the number of points.



(a) (b)

Figure 2: Cloud points capture by 3D scanner (a) original data (with >1.4 million points), (b) focused area (with 622,734 points) (all measurement in cm)

C. Data filtering process

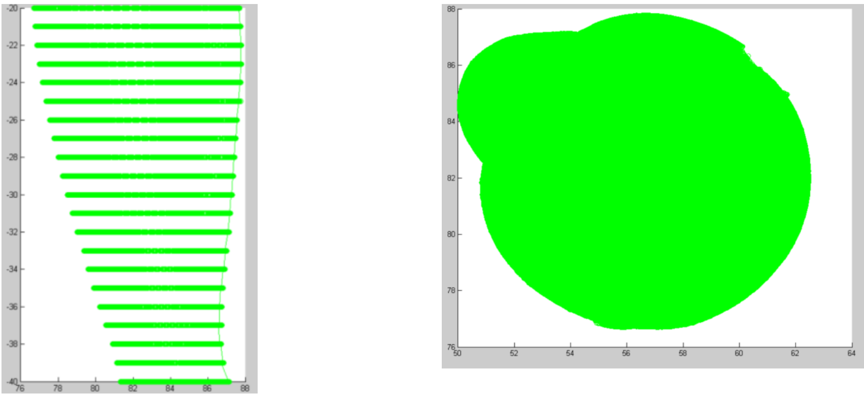
The first operation for the process is to rearrange the data according to their height (z-coordinate). The sorting operation can be executed using command *sortrows(z,x,y)* in Matlab.

If $A_1(x_1, y_1, z_1)$ to $A_n(x_n, y_n, z_n)$ are the points' coordinates where $z_1<z_2<\ldots<z_n$, then all the coordinate for the body part can be represented as A, where

$$A = \begin{bmatrix} A_1 \\ . \\ . \\ . \\ A_n \end{bmatrix} \tag{1}$$

Even though the data have been arranged, the total number of points is still similar. Thus, in the next operation, the initial height of z-coordinate was determined, and the distance between each height was set at 1 cm spacing. Each height is considered to represent a layer. All the points within the range of the height (+/- 0.25 cm) will be included in the layer. For example, if the initial height is 5 cm, then all points with z-coordinate within 4.75 cm and 5.25 cm are included in the first layer. The next layer is 6 cm, and all the points with a height between 5.75 and 6.25 cm are included in the second layer and so on. Figure 3 (a) shows all the developed layers from a side view.

However, the layers only show the shape at each section of the leg. As shown in Figure 3(b), the arrangement of the obtained points are still not in order, and their number is still large. Thus, a programming code was developed to arrange the data so that the point begins from the front of the body and move clockwise to the other surfaces.



(a) (b)

Figure 3: The developed layers after height arrangement (in cm) from (a) side view (b) top view

First, a centroid for each layer was selected. Centroid is the point at the centre of any shape, sometimes called the centre of area or the centre of volume. The coordinates of the centroid (G) are the average of the coordinates of all the points of the shape, and its formula is shown in (1) below.

$$G_j = \left(\frac{\sum_{i=1}^{n} x_i}{n}, \frac{\sum_{i=1}^{n} y_i}{n}, \frac{\sum_{i=1}^{n} z_i}{n} \right) \tag{2}$$

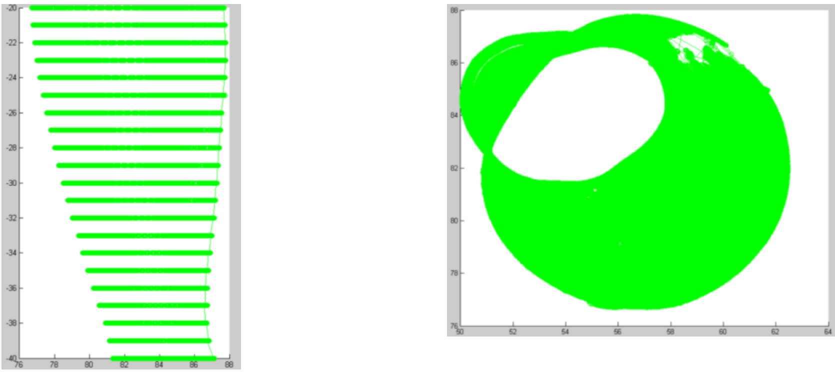
x_i, y_i, z_i is the coordinate of point i at layer-j. The centroid will become the layer's reference point.

The next step is to calculate the point's angle *(θ)*, from the centroid. It can be obtained by the following formula.

$$\theta = \arctan\left(\frac{y_i - y_G}{x_i - x_G}\right) \tag{3}$$

where x_i and y_i is the points' coordinate and x_G and y_G is the centroid's coordinate. All the points then sort according to their height and angle (command *sortrows (z, □, x, y)*).

Figure 4(a) and 4(b) show the result after the angle arrangement. The former shows the data points after rearrangement from the side view, and the latter shows the point's arrangement from top cross-section view.



(a) (b)

Figure 4: 229,011 data points after angle arrangement (in cm) from (a) side view, (b) top view

Nevertheless, as shown in Figure 4(a) and 4(b), the number of points is still large. For the selected area, the number of points is 229,011. Although more points will contribute to a more details output, the time it takes for processing will also increase. Thus, the total points for each layer are needed to be limited. Another programming code is written to address the aforementioned. In the previous programming code, all the points with similar height were included in the layer. But, in the new programming code, the points are also needed to be at a certain angle to be selected. For this research, 72 points were determined for each layer. This means that the data points in a given layer are separated by approximately 5 degrees or around 0.5 cm. Thus, any point which located +/- 1 degree from the predetermined angle will be included in the layer. If there is more than one point at each angle, an average coordinate will be calculated and selected. For example, if there are three points, P_{m-1}, P_m and P_{m+1} at angle 4.1, 4.9, 5.6-degree, then the coordinate for point at 5-degree (X_5, Y_5) is the average of the three points, which is

$$X_5=(x_{m-1} + x_m + x_{m+1})/3; \tag{4}$$
$$Y_5=(y_{m-1} + y_m + y_{m+1})/3; \tag{5}$$

Figure 5 shows the result after the second selection. It shows that the number of points is reduced significantly to only 1496 points.

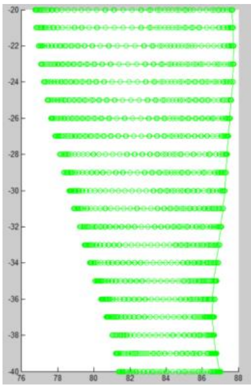


Figure 5: 1,496 data points after second filtering process from side view

D. Body measurement

In this research, the main measurement is circumferences of the body. The circumferences of the body were calculated by adding up all the distances between two consecutive points in each layer. Since each layer has the same z-coordinate, thus if P_1 (x_1, y_1) to P_n (x_n, y_n) indicate the points' number and coordinates in one layer, the circumference for the layer j is given by:

$$C_j = \sum_{i=1}^{n} \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} \tag{6}$$

However, this is only an approximation. The calculated circumference always underestimates the distances between two points. It is because equation 6 only consider the distances between the two points as a straight line, but the fact is the line is a curvature. Therefore, the calculated circumference is always smaller than the actual circumference. The higher the number of points used, the higher the accuracy of the calculation.

Result

Table 1 shows the comparison of circumference's results between previous (Salleh et al., 2017) and current research. It shows the locations of the measured layer (from bottom) and circumference of the layer. Both measurements are found to be identical, suggesting that there is no loss of information that transpires, although the data points have been substantially reduced.

Table 1: Comparison of circumference measurement

	Previous research	Current research
Height (cm)	Circumference (cm)	Circumference (cm)
0	21.3	21.3
1	20.9	20.9
2	21.1	21.1
3	21.6	21.6
4	22.2	22.2
5	23.0	23
6	23.8	23.8
7	24.7	24.7
8	25.6	25.6
9	26.6	26.6
10	27.5	27.5
11	28.5	28.5
12	29.5	29.5
13	30.6	30.6
14	33.3	33.3
15	32.4	32.4
16	33.3	33.3
17	33.9	33.9
18	34.5	34.5
19	34.8	34.8

Conclusion

This paper has developed a body measurement system using a handheld scanner. The process begins with the data acquisition using a handheld scanner. A computer programme, using Matlab, has been developed to transform the data into a 3D body model. The programme uses a mathematical model to filter the number of data of the body model. For a form of validation, the body circumference measurement results from this research were compared with a previous experiment. The results show that the developed programme can be used to measure body parts. Even though this research focused on measuring body circumferences, the system can be manipulated to measure other parameters as well, such as body volume and surface measurement. This research has further enhanced the capability of a handheld scanner, from just a scanner for 3D visualization and 3D printing, to a body measurement system.

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