3D Parametric Body Model Based on Chinese Female Anhtropometric Analysis

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Abstract. This study shows a 3D parametric body model construction based on the anthropometric analysis technique. Compared to the traditional anthropometric surveys, the 3D body scanner provides with more accurate body dimension information and not only traditional measurements but also new body shape measurements. An anthropometric survey was completed to collect 3D body information of Hong Kong female. A serious of 3D models was built upon these 3D scan data. A number of body dimensions and body shape information were extracted from the 3D models. Then body shape analysis were performed, such as bust shape analysis, front and back proportion analysis, body cross section comparison, correlation relationship between body dimensions and so on. Upon the analysis of the body information, a parametric body model was built, which was in a most common body shape of the Hong Kong female and able to change critical body demotions according to the user's inputs.

Keywords: 3D, parametric, body model.

1 Introduction

Computer aided design (CAD) has been a commonplace in many fields of industry nowadays. With the advancement in computer aided design (CAD) and computer aided manufacture (CAM), virtual mannequins begin to be adopted in various areas such as garment drape simulation [1], female figure identification [2] and virtual garment design [3]. Nicola D'Apuzzo [4] reviewed the existing market usage of 3D body scanning technology for fashion and apparel industry, virtual-try-on has became possible for the industry. Body model is an essential part in these applications, which provides garment designers with a virtual three-dimensional body model for them to refer their design to, to try on and to demonstrate their products in virtual environment. However there are some problems in body model that the body scan data is not in a feasible format for any commercially available CAD system, and whenever a different size body is required, a real human body of that specific size has to be scanned and the whole body model building process has to start over again[1, 5]. It will be costly relatively. Furthermore the 3D body model

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is usually very large, brings inconvenient in data storing. Some researchers has been working on the parametric body model [1], for new approaches to build the 3D body model. First, the original shape of the parametric body model is generated from a 3D body scan data, with a set of parametric surface and deformation algorithm it can easily change into different body sizes. On the other hand, it can integrate with CAD and CAM software. However there are still several limitations for the parametric body model. First one is how precisely the deformation algorithm can describe the body shape change. Although the original body model is built according to the real human or dummy scan data, but the accuracy of the deformation algorithm is not approved against any anthropometric data, in other words, it is not guaranteed that the parametric body model is changed according to the real human body shape variety. Secondly, different race, different age group of human has their unique way of body shape variety, which should be studied before setting the deformation algorithm.

This paper presents a new approach to build a 3D parametric body model. Firstly, study the various bodily profiles of the human body, obtained in the form of data clouds and avatars are extracted from body scanners database. Secondly, the morphological and topological profiles of the body parts or that are used in the 3D model design are studied in the digital format. Thirdly, these digital body model is built using common CAD software for easy integrate into other software.

2 Anthropometry Survey

The parametric body model is designed to be able to change itself into the desired body shape configuration accurately, so it is essential to develop a comprehensive understanding of body shape variations. 130 Hong Kong female aged 17-22 were scanned using the TC2 body scanner. Participants were recruited for the anthropometric studies launched by the Institute of Textile and Clothing of the Hong Kong Polytechnic University. In the recruitment process, participants were chosen who had reasonably symmetrical body proportions without any obvious deformities or postural problems caused by neurological or musculoskeletal diseases. Participants were scanned in a light color close-fitting undergarment, which allows 3D body scanner to capture the body shape while avoiding deforming it. Participants were positioned in an erect but relaxed posture, with arms and legs abducted slightly so that the cameras in the scanner could capture the full torso. The scan process finished in 10 seconds, and then the raw data was processed into the file format .obj and .rbd by the 3D body scanner software as the output. Then the critical measurements are extracted and analyzed to support the following research stages.

2.1 Girth Distribution Analyses

The body shape dimensions with a relatively distinct variations and belonging to the garment construction dimensions, according the ISO8559, are selected and applied statistical analysis. Because these dimensions are critical dimensions in garment design and the major dimensions change of the parametric body model will take place at these areas. These dimensions and the cup size are set to be the driving dimensions. The selected dimensions include: neck girth, bust girth, waist girth, abdomen girth, hip girth, bust width, neck to bust vertical length, bust to waist vertical length, waist to hip vertical length and shoulder length. Table 1 shows the distribution of the selected dimensions.

Table 1. Driving dimensions distribution

Dimensions	Mean (cm)	Standard deviation(cm)	$\mu \pm 3\sigma$ (cm)
Neck girth	33.6	2.0	27.6 to 39.6
Bust girth	83.5	6.6	63.7 to 103.3
Waist girth	70.0	5.7	52.9 to 87.1
Abdomen girth	80.2	7.6	57.4 to 103.0
Hip girth	93.0	5.9	75.3 to 110.7
Shoulder length	11.2	1.6	6.4 to 16.0
Bust width	17.1	1.8	11.7 to 22.5
Neck to bust vertical length	20.4	1.9	14.7 to 26.1
Bust to waist vertical length	18.2	2.4	11.0 to 25.4
Waist to hip vertical length	21.9	3.2	1.5 to 12.3

2.2 Breast Size Distribution Analyses

Breast size is an important and essential dimension for the women's foundation garments, anthropometric and figure classification. Breast and bra classification follows the ISO DIS 4416 stander (shown as Table 2), and the breast size distribution analyses results are shown in Table 3.

Table 2. ISO DIS 4416 preferred size scales for women's foundation garment

Underbust Girth(cm)	64	68	72	76	80	84	88	92
Bust Girth(cm)-Cup A	76	80	84	88	92	96	100	104
Cup B	80	84	88	92	96	100	104	108
Cup C	84	88	92	96	100	104	108	112
Cup D	88	92	96	100	104	108	112	116
Cup E	92	96	100	104	108	112	116	120
Cup F	96	100	104	108	112	116	120	124

Table 3. Breast size distribution

Underbust Girth(cm)	64	68	72	76	80	84	88	92	Percentage
Cup A	14%	18%	17%	6%	1%	1%	0%	0%	57%
Cup B	8%	12%	7%	3%	0%	1%	2%	1%	34%
Cup C	2%	5%	1%	1%	0%	0%	0%	0%	8%
Cup D	0%	0%	0%	0%	0%	1%	0%	0%	1%

2.3 Front and Back Proportion Analyses

Seldom research has been done on the relationship between the front half part and back half part of the body girths. As the body size grows, both the front and the back part of the girth are increasing, but at different rates. With the help of the 3D body scanner, the point cloud body model was generated. Then it was split into the front part and back part using a plane which is from the two side waist points intersecting the crotch point. Then the front half waist and hip girth are compared to the back part respectively. The result shown in Fig. 1 reveals that: as body size increasing, the front part of the waist is increasing faster than the back part, while the front part of the hip is increasing slower than the back part. When the parametric body model is changing its size, the cross sections shapes change should follow these rules.

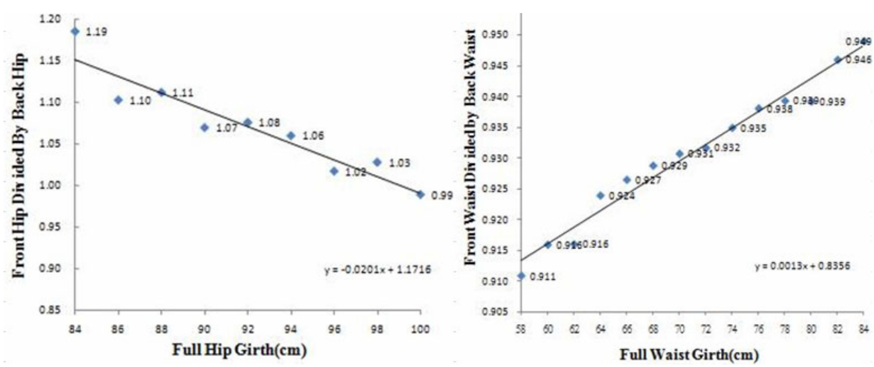

Fig. 1. Front and back proportion comparison

2.4 Relationship between Dimensions of Different Body Parts

If any dimension changes, it normally will affect the other body dimension as well. For example when the hip girth becomes larger, the abdomen girth will increase as well. To gain a further understanding of the relationship between these critical dimensions during size changing, the correlation relationships between several critical dimensions are figured out. A sample correlation coefficient (r), sometimes referred to as a Pearson Product-moment correlation, is a measure of the strength of the linear relationship between two variables. If we have a series of n measurements of x and y written as xi and yi where i = 1, 2, ..., n, r is rewritten as (1)

$$r_{xy} = (n\sum x_i y_i - \sum x_i \sum y_i) / (\sqrt{n\sum x_i^2 - (\sum x_i)^2} \sqrt{n\sum y_i^2 - (\sum y_i)^2}) \quad (1)$$

Its value ranges from -1.00 to + 1.00, with -1.00 representing a perfect negative linear relationship (as x increases, y decreases), 0.00 representing a total lack of linear relationship, and + 1.0 representing a perfect positive linear relationship (as x increases, y increases) between the variables. See Table 4, the results are similar to the correlation coefficient analyses results of anthropometric survey of US army(female) in 1988 [6], indicating these relationships are not only true of Hong Kong young female but also American young female. With the correlation relationship found, it is able to determine how the driven dimensions change following the driving dimensions of the parametric model. There are two driven dimensions: the scye circumference and under bust girth.

Table 4. Correlation coefficients between critical body dimensions

Correlation Coefficients	US army(female)	Hong Kong young female
Bust Girth - Shoulder Length	0.074	0.118
Bust Girth - Neck Girth	0.645	0.457
Bust Girth - Scye Circumference	0.768	0.708
Bust Girth - Waist Girth	0.863	0.706
Waist Girth - Hip Girth	0.740	0.774
Neck Girth - Shoulder Length	0.080	0.105
Bust Girth - Under bust Girth	0.875	0.907

3 3D Parametric Body Model

The shape of the 3D parametric body model was developed with the software Solidworks. It was controlled by some specific cross sections (see Fig. 3 and Fig. 4). To construct the shapes of these cross sections, the point cloud data of a normal size 12 full body forms are collected using the body scanner. Then filter the noise in the point cloud date. Connect the remaining points using B-spline method to generate the basic curves of the cross sections (Fig. 6). Compared to the point cloud data from the anthropometric survey, these basic curves are modified manually, in order to be more close to the most common body shape of the Hong Kong young women. Then the dimensions listed in Table 1 and the cup size were set to be the driving dimensions which are from the inputs of the user. And dimensions such as the scye-circumference and under bust girth were set to be the driven dimensions.

Here is an example to explain how the parametric work. When the user increase the waist girth, the parametric body model will first increase the front part and back part separately according to the rules given in section 2.3 until the whole waist girth reaching the value which user indicated. Then the driven dimensions, such as the scye circumference and the under bust girth will change following the driving dimensions as section 2.4 describes. Fig. 6 shows an example that the parametric model changes from dimensions size A to size B (See Table 5), monitoring the body shapes variation.

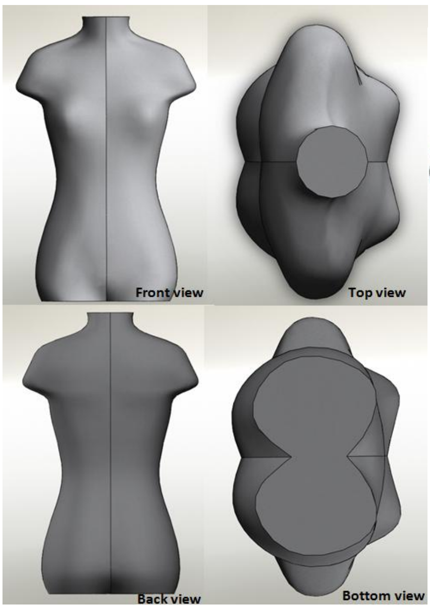

Fig. 3. Parametric body model

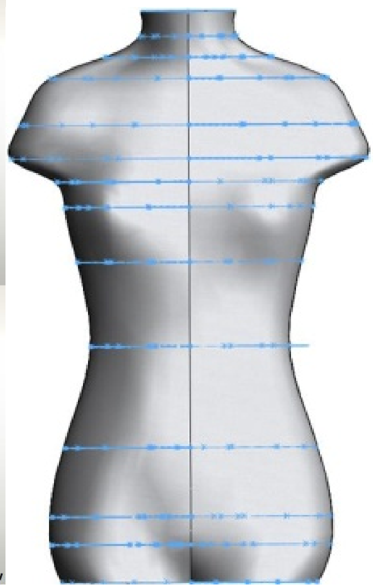

Fig. 4. The parametric mannequin shape is controlled by the cross sections

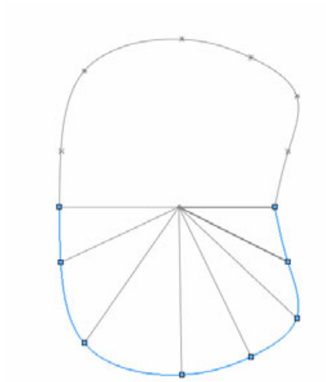

Fig. 5. The cross section at the bust level constructed by the points and B-spline line

Table 5. Size A and B

Measurements	Dimensions (cm)	
	A	B
Neck girth	11.2	10.5
Bust girth	86.0	80.0
Waist girth	62.5	55.5
Abdomen girth	82.0	77.0
Hip girth	93.0	85.0
Neck to bust vertical length	23.2	20.4
Bust to waist vertical length	16.5	14.0
Waist to hip vertical length	20.0	18.5

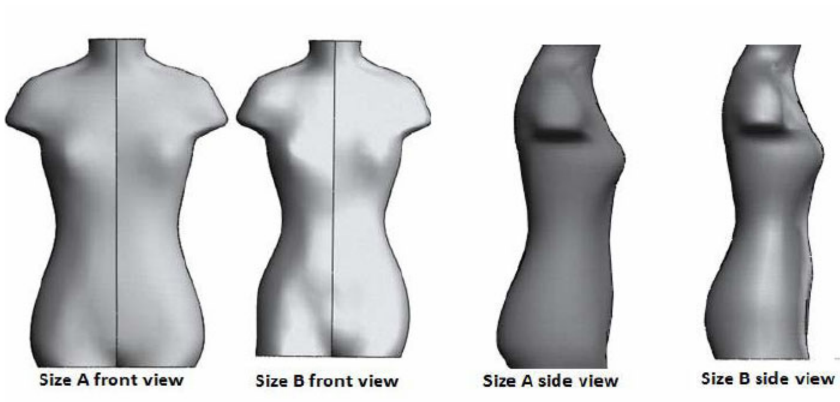

Fig. 6. Shape comparison between size A and B

4 Conclusion

A 3D parametric body model has been built based on the anthropometric survey of the Hong Kong young women. It can monitor most of the various body figure types of the women in this age group, by simply inputting several driving dimensions. The relative analyses have been performed to develop a comprehensive understand for the human morphology. The outcome of the study provides valuable anthropometric data and a 3D paramedic body model to be used in garment drape simulation, female figure identification and virtual garment design. Further work will include bring in more driving dimensions and more driven dimensions to refine the shape and make the body model more flexible. A benchmark system will be added to check whether the user inputs are reasonable dimensions. And a user interface will be built as well to make the system more user-friendly.

References

1. Kim, S., Park, C.: Parametric body model generation for garment drape simulation. Fibers and Polymers 5(1), 12–18 (2004)
2. Simmons, K., et al.: Female figure identification technique(FFIT) for apparel part I: describing female shapes. Journal of Textile and Apparel, Technology and Management 4(1) (2004)
3. Hardaker, C.H.M., Fozzard, G.J.W.: Towards the virtual garment: three-dimensional computer environments for garment design. International Journal of Clothing Science and Technology 10(2), 114–127 (1997)
4. D'Apuzzo, N., Consulting, H.: 3D body scanning technology for fashion and apparel industry. Videometrics IX. In: Beraldin, J.-A., Remondino, F., Shortis, M.R. (eds.) Proceedings of the SPIE, vol. 6491, p. 64910O (2007)
5. Carrere, C., et al.: Automated garment development from body scan data. National Textile Center Annual Report I (2000)
6. IL, N.U.E., et al.: Anthropometric Survey of US Army Personnel (1988): Correlation Coefficients and Regression Equations (1990)