Model Reconstruction of Human Buttocks and the Shape Clustering

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Abstract. The purpose of this study is to reconstruct the buttock model of Chinese young men, and categorize the buttock model by *k*-means clustering algorithm. Thirty men participated in our anthropometric study. The buttocks of subjects were pasted with the mark-points: coccyx (upper margin), trochanters (both sides of the margin), and the middle points on separation line between hip and thigh (lower margin) as the points of the boundary mark-points; ischial tuberosities, anus, as the function mark-points. Three-dimensional (3D) points cloud data, obtained by scanner, was imported into reverse engineering software for the reconstruction of buttock surface model. Then surface models were imported into CATIA software. The horizontal width, the vertical width, and the thickness of the buttocks were measured in 3D shape model. The *k*-means clustering algorithm was used to individually cluster the dimensions of horizontal width, the vertical width, and the thickness into two groups. The 3D buttock model was successfully reconstructed by 3D scan technology. The models of buttock can be categorized into eight types: long - wide - thick, long - wide - thin, long - narrow - thick, long - narrow - thin, short - wide - thick, short - wide - thin, short - narrow - thick, short - narrow - thin.

Keywords: Reconstruction, anthropometric, *k*-means clustering algorithm, three-dimensional (3D), buttock model.

1 Introduction

Anthropometry data is one of the most important fundamental tools in the design and ergonomic evaluation of a product; it is the design basis of products related to human dimension, which will improve the comfort of products by human-match-product reasonably [1]. The traditional anthropometric measurement tools including tape measure, calipers, gauges and special measuring instrument for human data acquisition, which leave out the spatial relationships between those measured item. When products need to be adapted to the parts of the human body, the traditional anthropometric data is insufficient to guide the design of the product, for lack of such shape information and spatial relationship information. However, the emergence of non-contact three-dimension(3D) measurement instrument greatly improve the

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suitability between product and human body, making the tailor-made and personalized products, such as apparel, shoes, hats, helmets, become a reality. The three-dimensional anthropometric undoubtedly provide richer information for ergonomic design and safety assessment of the product [2].

Many researchers have established three-dimensional surface model of different body part, and they were applied to product design and evaluation related to human body, such as helmets [3, 4], shoes [5, 6, 7,], cushion [8], apparel [9] and so on.

With continuous improvement of people's life quality, customers require more accurate size system to help them buy more suitable products. Hence, good product design has never been more closely related with correct anthropometric measurements data. Typically, buttock model meets with extensive needs in producing comfortable cushion and good pants type. First, for seat shape, it is designed to be symmetrical simulating the shape of the buttocks, to assure hip part gets enough support, and also its contact area with the surface of chair shall increase, thereby to reduce the pressure, and to relieve the buttocks extrusion fatigue caused by obstruction of blood circulation [10]. Second, when it comes to pants designs, designers often encounter fundamental problems like waist-hip differential, waist-hip loose amount and upper crotch area movement deformation. To solve these issues, it is necessary to refer to the size of the hips, such as hip circumference, hip thickness [11]. Therefore, another cloth type: skirt shape, similar to pants, relates to human waist and hips form [12]. Thus to conclude, effective hip shape model has important significance for product design.

Currently, China’s national size standard defines adult female’s breast and waist circumference as two basic components characterizing clothes size, chest-waist differential and waist-hip differential are used to categorize human body type into 4 classes: Y, A, B, C. However, studies indicate that this method of classification does not well reflect the female body shape variance, the features of female body are not correctly classed and represented, and also suggest that body shape classification should be processed separately: by different body part such as chest, waist and buttock independently[13]. According to youth women pants size research, 57% of female pants do not fit, in which major problems are with waist-buttocks ratio unfitness, tight crotch etc[14]. In traditional pants production process, templates are built based on standard body type by region. These templates meet with general need of normal people, but have many limitations. People with flat or prominent bottom wearing these pants may come across different kinds of problems: prominent type finds the back crotch curve line too short, and their bottom strained. Flat type is troubled with a fat bottom appearance and has loose crotch [15]. Traditionally, people construct a structure diagram of trousers and then deal with these issues qualitatively, by means of lengthening or shortening side seam or back crotch curve [16]. Flat/prominent body type crotch structure has been studied quantitatively, but no researchers consider solving this problem by reclassify the bottom sizing system [17].

There is no research in the establishing of 3D buttock model and sizing system. When establishing the buttock model, the size with width and length, and thickness need to consider. So the purpose of this study was to establish human buttock 3D model, and cluster analysis the samples using the *k*-means algorithm.

2 Materials and Method

2.1 Materials

3D scanner with raster display technology (3D CaMega, China, accuracy up to 0.02mm), the black mark- point pieces, white underwear.

2.2 Subjects

Thirty undergraduate men, height range: 160-183cm, weight range: 47-90kg. All subjects were volunteers and were paid for their participation.

2.3 Scan and Reconstruction of Buttock Model

Mark- Points. Boundary mark- points: coccyx (upper margin), trochanters (left and right margin), the middle points on separation line between buttock and thigh (under margin).

Function mark- points: ischial tuberosities, anus.

The mark-points are shown as in Fig. 1.

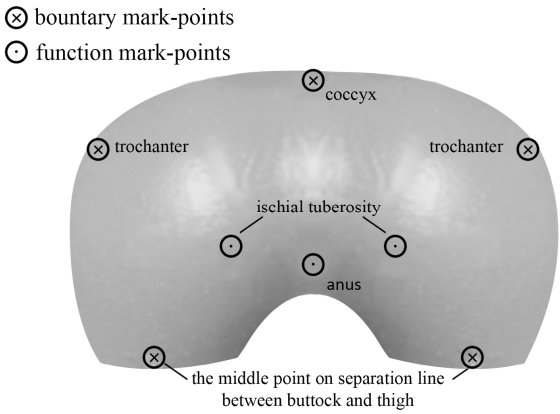

Fig. 1. Mark-points on buttock surface

Measurement Posture. Subjects need to keep bending posture, upper body being perpendicular to the thigh, while ensuring that the plane of buttock being parallel to the camera lens plane.

Design of Coordinate System. The design of coordinate system is based on space analytic method, that the buttock plane (a plane parallel to the camera lens plane) is set as XY plane, the vertical direction through the surface is set as the Z-axis (i.e., space or Z coordinates), and pointing posteriorly; the XZ plane is parallel to the

horizontal plane, and Y-axis is the perpendicular through the plane, and pointing cranially; frontal plane through the anus point is set YZ plane, through which plane perpendicular is the X-axis, and pointing to the right is positive direction.

2.4 Reverse Reconstruction of Buttock 3d Model

The result of the 3D scan was a set of spatial points with their corresponding 3D coordinates named the point cloud. Several steps were employed to model the acquisition process. Firstly, the point cloud was entered into the Geomagic Studio (Geomagic,USA), a reverse engineering software. The point-cloud model was then packaged into a polygon model by filling the holes, by processing the edges to form a basic continuous polygonal patch. Secondly, the model was converted to Nurbs surface in order for being able to be imported into the industrial modeling software. Then, the point-cloud model became a surface model by establishing a curved path in Geomagic Studio. The special mark-points were marked on the surface model. The final surface model and the feature points were output as Nurbs model. Thirdly, Catia (Dassault Systemes S.A., Franch) directly imported the Nurbs model created from Geomagic with the feature points and characteristics of surface points for 3D surface reconstruction of buttock.

2.5 Measure the Dimensions

The buttock model, reconstructed in Gemagic,was imported into CATIA (Dassault Systemes S.A., Franch). The horizontal width (the left edge to the right edge of the buttocks), the vertical width (the upper edge to the lower edge), and the buttocks thickness (the veticle distance from ischial tuberosity to the plane of trochanters) were measured in 3D shape model.

2.6 Statistical Analysis

The *1*-st, *5*-th, *50*-th, *95*-th and *99*-th percentile, mean and standard error values of all three measured dimensions (the horizontal width, the vertical width, and the buttocks thickness) were determined using standard statistical procedures by using the SPSS 18.0 (IBM Corporation, Chicago, USA). The k-means clustering algorithm was used to individually cluster the dimensions of horizontal width, the vertical width, the buttocks thickness into two groups.

3 Results

3.1 Reconstruction of Buttock Model Based on 3d Scan

To eliminate errors produced from model reconstruction and body shaking during the scan process in a certain extent; all subjects need to be scanned twice. The average values across these two trials were reported. During the data processing, the twice scan data of one subject was averaged firstly, and then performed the group data processing. The reconstruction buttock model is shown in Fig. 2.

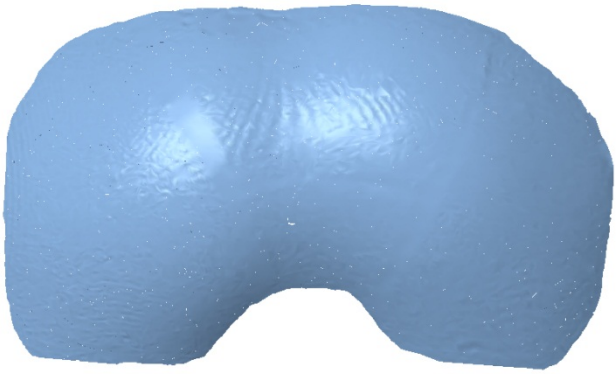

Fig. 2. The reconstruction buttock model

3.2 Percentile Statistics

Three measurement dimension values were measured from three-dimensional buttock model of thirty subjects, the horizontal width, the vertical width, and the buttocks thickness. *1*-st, *5*-th, *50*-th, *95*-th, *99*-th values were obtained through data processing, as shown in Table 1.

Table 1. The *1*-st, *5*-th, *50*-th, *95*-th, *99*-th values of measurement dimensions

	The horizontal width(mm)	The vertical width(mm)	The thicness(mm)
1-st	94.60	163.58	14.37
5-th	96.49	185.52	17.84
50-th	133.96	239.23	50.20
95-th	186.62	309.62	80.87
99-th	192.88	319.12	83.05

3.3 Clustering Analysis

The horizontal width, the vertical width, and the thickness of buttock model are individually divided into two groups by *k*-means clustering algorithm bottom. And then based on the value of the three measurement project classification, permutations

Table 2. Eight categories of clustering results

	The horizontal width(mm)	The vertical width(mm)	The thickness(mm)
Long-wide-thick	159.85	262	63.31
long-wide-thin	159.85	262	27.12
long-narrow-thick	126.06	262	63.31
long-narrow-thin	126.06	262	27.12
short-wide-thick	159.85	234	63.31
short-wide-thin	159.85	234	27.12
short-narrow-thick	126.06	234	63.31
short-narrow-thin	126.06	234	27.12

and combinations of the eight categories of the buttocks model: long - width - thickness, long - wide - thin, long - narrow - thick, long - narrow - thin, short - wide - thick, short - wide - thin, short - narrow - thick, short - narrow - thin.

4 Conclusion

In this study, the three-dimensional model of the human buttock was successfully reconstructed by three-dimensional scanning technology. The buttock models included the points of boundary points, anus, ischial tuberosities. Eight categories of the buttock models were formed by the cluster analysis of the horizontal width, the vertical width, and the buttocks thickness.

5 Discussion

We didn't find a principle for the categorization of buttock model, and so far, the buttock model haven't been used to the design and evaluation the product relative to buttock. So the rationality of the categorization of buttock model can't be verified and analyzed.

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