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Measurement of Human Body's Feature Dimensions Based On The National Standards

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Abstract. In order to recognize and extract feature dimensions automatically from point clouds of human body, a method based on National Institute of Standards is proposed. Using the data provided by the National Institute of Standards GB10000-1988 to divide the search region of each feature point firstly. Then, extracting the feature points in the search region by comparing the coordinate values and the distance from point to straight line with other points . The method has nothing to do with the body shape and improves the robustness of feature point extracting. In the aspect of body dimension's measurement, the critical feature dimensions are calculated by intersection-contour perimeter method and distance between two points methods.

Introduction

In the aspect of human body's feature-points extracting, scholars have done a lot of fruitful research at home and abroad. The main applied methods are template method, function method and geometry analysis method. The template method extracts feature points through mapping a predefined template to the human point cloud, the related research on this method as: Nurre [1] took the human body as a stick template which represents head, arms, legs and torso respectively, then, divided the human body into several segments in accordance with this template. The template method has higher positioning accuracy than other two methods, but the calculation process is complex. The function method identified the feature points by setting up a specific function for each feature point. Dekkeer [2] developed the discriminant function based on the human body geometric model, then, extracted the feature points by the discriminant function. The curve and surface fitting process in the function method is complex and time-consuming. The geometry analysis method extracted feature points based on human scale and the feature of human point clouds. Dourous [3] got the two-dimensional points from the intersection of horizontal plane and the point clouds, fitted the two-dimensional points with B-spline curve, then, detected the feature points by analyzing the structural characteristics of these curves.

This paper made use of the intersection of horizontal plane and the point clouds to obtain two-dimensional body contour, and extracted the feature points by analyzing the two-dimensional body contour. Unlike the existing methods, based on the analysis of the data in GB 10000-1988 [4], we carved out each feature point's search region of different gender, and then, searched the body markers defined by GBT 5703-2010 [5] in the search region. This method improves the searching efficiency and algorithm robustness greatly. In the aspect of extracting feature points, we divided the human feature-points into two categories: one is the feature points which can be extracted by comparing the coordinate values, such as Chest point and Waist point. The other is bifurcation points which can be extracted by comparing the distance between point and straight line. Finally, the critical feature dimensions are calculated by Z-axis value difference method and intersection-contour perimeter methods.

Pretreatment of the 3D human body point cloud

The format of human point clouds used in this paper is OBJ. During the scanning process, the human body should be maintained the standing posture, limbs should be separated naturally, furthermore, upper limbs should be separated from the body and maintained a certain angle (15°~45°) with the body. We used a reverse engineering software named Geomagic studio to complete the work of noise elimination and coordinate transformation. Fig 1 shows the human body model with pretreatment.

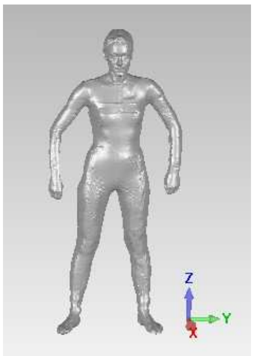

Fig 1. Human body point clouds model

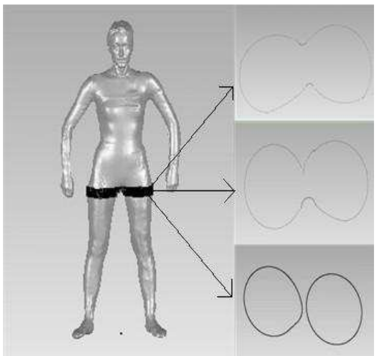

Fig 2. Search region and cross-sectional profile

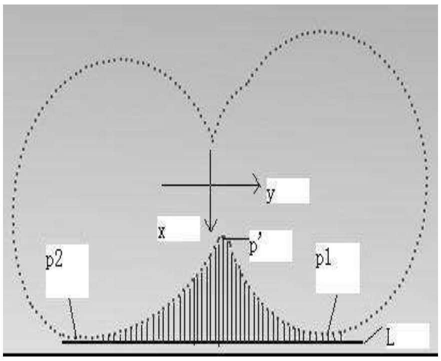

Fig 3. Perineum point extraction schematic

Feature point extraction

Before measuring the body size, we had to find the feature points on the body contour and the feature plane which contains the feature points. In this paper, the direction of human body model height is Z-axis, sorted all point coordinates in descending order in accordance with their Z-axis values, and in the data stored list, the first point is the head point, that is $P_H(x_H, y_H, z_{\max})$, the last point is the foot point, that is $P_F(x_F, y_F, z_{\min})$. The human body model's height value H can be calculated as: $H = |z_{\max} - z_{\min}|$; $z_{\max} \in P_H$, $z_{\min} \in P_F$. According to the basis data given by GB 10000-1988 and the study of human proportion in Clemson University in the USA, we got the ratio between height and feature points of the human body. Table 1 lists the ratio relationship.

Table 1. The ratio relationship of male and female adult in China

Gender	Male adult in China (18~60)			Female adult in China (18~55)		
Project Percentile	5	50	95	5	50	95
Eye height	0.931H	0.934H	0.938H	0.924H	0.926H	0.929H
Shoulder height	0.809H	0.815H	0.820H	0.805H	0.810H	0.814H
Waist height	0.603H	0.638H	0.618H	0.606H	0.612H	0.617H
Hip height	0.480H	0.489H	0.493H	0.474H	0.481H	0.488H
Perineum height	0.460H	0.471H	0.482H	0.454H	0.466H	0.477H
Tibia height	0.258H	0.265H	0.271H	0.254H	0.261H	0.268H
Upper arm length	0.183H	0.187H	0.190H	0.177H	0.181H	0.186H
Thigh length	0.270H	0.277H	0.288H	0.271H	0.279H	0.287H
Calf length	0.214H	0.220H	0.227H	0.211H	0.220H	0.227H

In Table 1, word "H" represents height of the human body; percentile represents the level of a certain size data of the body. Take the 95th percentile of body size for example, it means that there are 95% of the individual's size value less than the 95th percentile value in the crowd, and 5% greater than this value. We used the 5th and 95th percentile values.

At first, we determined each feature plane's search region S. We took the 5th percentile of the cross-section set of points as the lower limit of the search region, the 95th percentile as the upper limit. Took Waist point and perineum point to display how to extract the two types of feature points.

(1) The procession of Waist point extraction

① Get the lower and upper limit of the cross-section set of points: $S_H = \{P_{Hj} = (x_{Hj}, y_{Hj}, z_{Hj}), j \in N\}$, $S_L = \{P_{Lj} = (x_{Lj}, y_{Lj}, z_{Lj}), j \in N\}$.

② Make S_i the i[th] cross-section set of points, $L < i < H$. S_{i-1}, S_i, S_{i+1} are three adjacent cross-section set of points. Thus

$$y_{i\text{-}1\max} = \max\{y_{i\text{-}1j}, P_{i\text{-}1j} \in S_{i\text{-}1}\},\ P_{i-1j} = (x_{i-1j}, y_{i-1j}, z_{i-1j}) \tag{1}$$

$$y_{i\max} = \max\{y_{ij}, P_{ij} \in S_i\},\ P_{ij} = (x_{ij}, y_{ij}, z_{ij}) \tag{2}$$

$$y_{i+1\max} = \max\{y_{i+1j}, P_{i+1j} \in S_{i+1}\},\ P_{i+1j} = (x_{i+1j}, y_{i+1j}, z_{i+1j}) \tag{3}$$

③ Make the rule: if $y_{i\max} < y_{i-1\max} \&\& y_{i\max} < y_{i+1\max}$, else S_i is the feature plane which contains Waist point. $P_{ij} = (x_{ij}, y_{i\max}, z_{ij})$ is the Waist point we want, and the other Waist point can be extracted according to body symmetry.

(2) The procession of Perineum point extraction

① Get the search region of Perineum point and its lower and upper limit of the cross-section set of points: $S_H = \{P_{Hj} = (x_{Hj}, y_{Hj}, z_{Hj}), j \in N\}$, $S_L = \{P_{Lj} = (x_{Lj}, y_{Lj}, z_{Lj}), j \in N\}$.

Fig. 2 shows search region, upper limit set of points, target set of points, lower limit set of points.

② Make sure whether the profile curve connectivity or not from the lower limit of cross-section set of points S_L. The rule of determining whether connectivity or not : Sort the Y-axis coordinate values of all the points on the cross-section in ascending order, calculate the difference between two djacent points in the Y-axis direction. If the difference is greater than 5mm, thus the cross-section curve is not connected.

③ Make S_i the i[th] cross-section set of points, $L < i < H$. Find the two points P1 and P2 which have the greatest X-axis coordinate value in first and second quadrant respectively by comparing the distance from point to straight line with other points , that is, $P1 = (x_{i\max}, y_i, z_i)$, $L < i < H$, $y > 0$; $P2 = (x_{i\max}, y_i, z_i)$, $L < i < H$, $y > 0$. Compare the X-axis coordinate value of P1 and P2, and make a straight line parallel to the Y-axis L through the X coordinate value of greater point, as show in Fig 3.

④ Calculate the projection distance D between line L and the points which located between P1 and P2 , and make the largest point P'.

⑤ Compare all the projection distance D in turn, and the cross-section point set with the largest D is the feature plane where Perineum point located, then Perineum point can be found.

Measurement of body dimensions

We used the Z-axis difference method to calculate such feature dimensions as Eye height, Shoulder height, Hip height, Etc. The Z-axis difference method : $l_x = z_x - z_{\min}$, z_x represents the height of feature point, $z_{\min}$ represents the Z coordinate value of foot point. After we got some important feature points' height value, the rest feature points' height can extracted by proportionality rule. We used intersection-contour perimeter methods to calculate such feature dimensions as Waistline, Bust, Hips, Etc. The intersection-contour perimeter methods: assuming that the intersecting point set of feature plane and human body point clouds is $X_x = \{P_i, i = 1,2,...,n\}$, then the formula of horizontal circumference corresponding to the feature point x is

$$S_x = \sum_{i=1}^{n-1} l(P_i, P_{i+1}) \tag{4}$$

$l(P_i, P_{i+1})$ represents the distance between P_i and P_{i+1}.

Measurement results and error analysis

We applied the algorithm to a number of different human body point clouds data for automatic dimensional measurement, in contrast to it, we got the feature size through the measurement capabilities of Autodesk Inventor software to instead precise manual measurement as a reference. Select four samples and several important body dimensions to compare. The measurement results and error are listed in Table 2.

Table 2. Measurement results and error

Projection	Our algorithm measurement results（cm）				Atuodesk measurement results （cm）				Error(cm)	
	Female (1)	Female (2)	Male (1)	Male (2)	Female (1)	Female (2)	Male (1)	Male (2)	Avg	Max
Height	154.5	160.0	165.6	178.6	154.4	159.9	165.8	178.3	0.18	0.30
Arm length	51.6	53.4	55.3	61.8	51.4	53.8	55.2	61.6	0.23	0.40
Thigh length	70.4	72.8	75.4	82.0	70.5	72.7	75.1	81.8	0.18	0.30
Neck girth	35.1	37.4	41.8	39.4	34.8	38.1	41.7	40.1	0.45	0.70
Bust	91.0	99.5	101.9	86.1	91.4	99.9	101.2	86.4	0.45	0.70
Waist girth	72.6	67.8	96.0	79.2	72.5	67.0	96.4	78.8	0.43	0.80
Hips	84.6	91.0	84.5	87.4	84.2	90.6	85.3	87.9	0.53	0.80

GB/T 23698-2009 [6] lists the maximum allowable difference between the 3D scan measurement and the traditional measurement, the permissible error of the linear dimensions of the body height is 0.4cm and the permissible error of the girth dimensions of the body is 0.9cm. As showed in Table 2, the values extracted by the algorithm in this paper meet the error requirement which indicates that the proposed algorithm is accurate on extracting feature points.

Summary

We extracted feature point coordinates by setting search region and calculated the relevant dimensions automatically according to the definition of Clothing and Textile. Through the analysis of the error, the body dimensions we obtained can meet the accuracy needs of the garment industry. The follow thing we ought to do is improving the robustness of the algorithm and measurement accuracy.

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