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The Registration of Back and Front Body Surfaces Based on the Markers

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Abstract: When developing the 3D body scanners, because the measurement range of equipments is limited and the body surface is complicated, the body is scanned from the back and the front simultaneous and then the two parts are registered to get a whole body model. Based on 3D geometric transformations, the least square method is employed to calculate the transition matrix with minimized error. The experiment results show that this method is rapid, accurate, stable and simple.

Keywords: 3D body measurement, point cloud, registration, 3D geometric transformation, linear least square

1. Introduction

The 3D body measurement is the main characteristic of modern anthropometry and it is a useful technique with applications in the apparel industry, human systems engineering and medical field [1]. A 3D body measurement system merged the knowledge of optics, image processing and mechanics [2]. Because the measurement range of equipments is limited and the body surface is complicated, the whole body data can't be acquired by directly measuring. To solve the problem, the body need to be measured from several directions, and then the different parts are registered to get a whole body model, this is multi-view registration.

The commonly used methods of registration include resorting to supporting tools, using the surface features and iterative closest point (ICP). The supporting tools include turntable [3] [4], markers [5] [6], ball calibration [7] and assisting target [8] [9]. The key of using the surface features method is to determine the corresponding relationship between the point clouds. Maybe the relationship can be determined by extracting the bitangent surface features [10] or by curvature and normal vector [11]. The ICP algorithm aims to find the transformation between a cloud of points and some reference surface by minimizing the square errors between corresponding points [12] [13].

In this paper, the body is scanned from the back and the front shown as Figure 1. The markers are pasted on the body. The front and the back cameras capture the body images simultaneous. The point cloud of the front and the back are obtained respectively by feature extracting and stereo matching of the images from two cameras. Based on the 3D geometric transformations, least square algorithm is used to extract the transition matrix which is the minimized the transition error and then register the markers to get a whole body model.

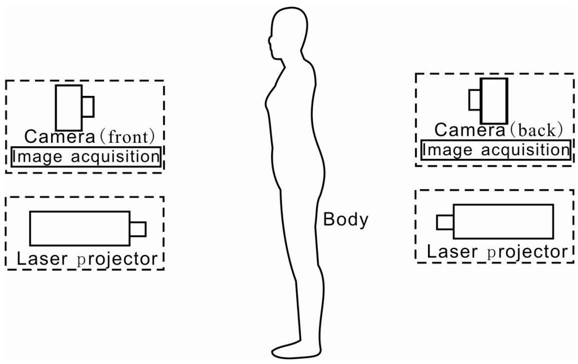

Figure 1 The registration of front and back

2. The registration of point clouds

2.1. 3D geometric transformations

3D geometric transformations describe the geometry conversion from one state to another according to a certain rule. In the process of geometric transformations, (n+1)-dimensional vectors are commonly used to express n-dimensional vectors, that is homogeneous coordinates [14]. For the point (x, y, z) in 3D space, the homogeneous coordinate correspond to (hx, hy, hz, h), generally h=1.

The points' transition matrix in 3D space can be described as

$$T = \begin{bmatrix} a & b & c & p \\ d & e & f & q \\ g & h & i & r \\ l & m & n & s \end{bmatrix}$$

T is a 4*4 matrix. It can be divides into four submatrixs:

Sub matrix- $\begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}$ causes scale, rotation and shearing transformation.

Sub matrix- $[l \quad m \quad n]$ causes translation transformation.

Sub matrix- $\begin{bmatrix} p & q & r \end{bmatrix}^T$ causes projective transformation.

Sub matrix- $[s]$ causes full-scale transformation.

The points registration belongs to rigid transformation, so $\begin{bmatrix} p & q & r \end{bmatrix}^T = \begin{bmatrix} 0 & 0 & 0 \end{bmatrix}^T$ and $[s] = [1.0]$.

Suppose point set P is the back side markers and the homogeneous coordinate is

$$P = (x_i, y_i, z_i, 1)(i = 1,2,3,\cdots,n)$$

Point set Q is the front side markers and the homogeneous coordinate is

$$Q = (x_i^{'}, y_i^{'}, z_i^{'}, 1)(i = 1,2,3,\cdots,n)$$

The relationship between P and Q is

$$PT = Q \tag{1}$$

2.2. Linear Least Square Problem

Least squares method is one of the most commonly used means to process and analyze data. It is to solve the unique solution of physical parameters by known parameters and mathematical model. For the given equation

$$AX = B \tag{2}$$

For the least square solution of equation (2), it is to make

$$\varphi(x_1, x_2, \cdots, x_n) = \min \sum_{i=1}^{m} [b_i - (\sum_{j=1}^{n} a_{ij} x_j)]^2 \quad X \in R^n$$

If equation (2) has solution, it is the least square solution [15]. Based on the principle of least squares, for $X \in R^n$

$$\frac{\partial \varphi}{\partial x_j} \sum_{i=1}^{m} [b_i - (\sum_{j=1}^{n} a_{ij} x_j)]^2 = 0 \qquad (j = 1,2,\cdots,n) \tag{3}$$

The equation (3) can be changed into

$$\sum_{i=1}^{m} \sum_{k=1}^{n} \varphi_{ik} \varphi_{ij} x_k = \sum_{i=1}^{m} \varphi_{ij} b_i \qquad (j = 1,2,\cdots,n)$$

Its matrix form is

$$A^T AX = A^T B \tag{4}$$

$A^T A$ is a positive definite matrix and its inverse matrix can be calculated, so

$$X = (A^T A)^{-1} A^T B \tag{5}$$

2.3. The Process of Registration

(1) Determine the corresponding markers, the back markers is $P = (x_i, y_i, z_i, 1)(i = 1,2,3,\cdots,n)$, the front markers is $Q = (x_i^{'}, y_i^{'}, z_i^{'}, 1)(i = 1,2,3,\cdots,n)$.

(2) Calculate P^T, $P^T P$ and $P^T P'$.

(3) Solve the equation $P^T PT = P^T P'$, the unknown parameters in matrix T can be got.

3. Error Analysis

Theoretically, the body can be registered together only if paste three markers on the body. Practically, the relative position of the markers in front and back body clouds are not perfectly uniform due to the measurement errors which are caused by environment of measuring, the edge distortion of cameras or the shadow of light. The registered body may be out of shape. So in order to get better result, the markers should be more. With the increase of markers, the true body data may be disturbed and the computing speed will be affected. The Table 1 is the error with different markers pasted on the body. In table 1, *e* is the sum of every error. After the front and back are registered together, every pair of markers has error and the error of *ith* pair is e_i, then

$$e=e_1+e_2+\ldots+e_n$$

Table 1 the Errors of Different Markers

The number o f markers	e (mm)
3	9.84673
6	7.10258
12	4.00032
24	3.78891

Figure 2 includes (a), (b) and (c), (a) is the body of front, (b) is the body of back, (c) is the whole body model after registered. Six markers are pasted on the body.

4. Conclusion

Multi-view registration plays important roles for researching 3D body measurement systems. The paper discusses the registering method of based on markers. The markers are pasted on the body before scanning body. By 3D geometic transformations, the corrsponding markers in different view are registered together. The transition matrix is calculated by the least square with minimized error. The result shows this method is practical with simple operation, high accuracy and rapid speed.

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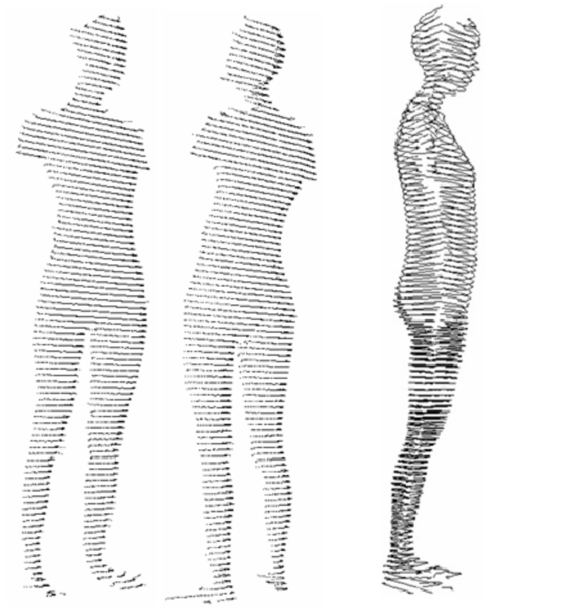

Figure 2 The registration of front and back

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