Fast 3D Body Measurement Based on Multi-directional Point Cloud Piecing

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Abstract. In order to realize fast, accurate and device-lightweight 3D body measurement, this paper proposes a quick measurement scheme which obtains measurement results by combining multi-directional human point cloud data. In this paper, the depth camera captures the point cloud data in front, side and rear of the human body, and combine the point cloud data with the skeleton point data provided by the depth camera somatosensory function. Taking the measurement of waist circumference as an example, the method of extracting the point cloud data of the waist is described. The curve equation of the waist curve is obtained by polynomial curve fitting with the discrete points. Finally, the length of the waist curve is calculated by the integral method. The measurement results are satisfactory.

1. Introduction
3D body measurement technology plays a key role in virtual fitting[1], electronic tailoring, etc. In practical applications, apparel manufacturers are more inclined to quickly measure the program to reduce the waiting time of the measurement object. The 3D anthropometric solution requires high-precision and complete 3D mannequins with expensive large laser scanners[2], or a portable scanner to slowly bypass the human body to build a complete human grid model, spending a lot of time scanning and scanning the human body[3]. The surface reconstruction of the model works. However, the geometric features of the human body such as the waist, chest and other parts are obvious, there is no complicated spatial relationship, and the 3D human body mesh model after surface reconstruction contains a large number of topological structures, patch vector information, and helps the actual length measurement work[4][5]. This is a small 3D anthropometric solution that uses a lower cost depth camera for data collection and eliminates the traditional 3D reconstruction process by scanning the human body from three directions and splicing multiple human point cloud models. Measurement data can be obtained from the point cloud model.

2. Multi-directional human point cloud data acquisition
This article uses Microsoft's kinect2.0 as a point cloud data collection device, calling Kinect SDK2.0 and point cloud library PCL1.8 for data acquisition and storage. Among them, kinect2.0 is the second generation of somatosensory device produced by Microsoft. Real-time capture of the depth information of the object in front, and at the same time can identify the human body and give the position information of the key parts of the human body. The depth information of the visualization is shaped like a cloud composed of spatial lattices, so the depth data can also become point cloud data, and the point cloud library PCL is a tool library that collects a large number of 3D point cloud data.
processing methods. Figure 1 shows the process of human body point cloud model stitching and interest area extraction obtained by Kinect.

3. The combination of the human point cloud model

Infrared signal reception is affected by angle. Kinect uses dense infrared speckle for distance measurement. As shown in Figure 1(a)(b), when the measuring object plane is at an angle relative to the infrared emitter, the infrared beam projected onto the same plane is reduced, and the Kinect is acquired. The number of point clouds is also reduced, the noise immunity of the point cloud data is reduced, and the measurement error is increased. Figure 1(c) is a sample of the point cloud densely arranged in the front, and Figure 1(d) is the side sparse row. A sample of the point cloud of the cloth, and the more the camera is tilted toward the right side, the greater the inclination is [6].

Figure 2 shows the waist contours of four human bodies. The toe of the footprints in the contours indicates the specific orientation of the measurement object. Figure 2 (a) (b) (c) shows the front and side of the measurement object, respectively. The distribution of the mass of the point cloud data collected on the back side facing the depth camera respectively, wherein the green part indicates a region with high density of arrangement and strong anti-noise ability, and the yellow part indicates that the point cloud arrangement is gradually sparse, and the anti-noise ability is weakened. The area and the red area indicate that although the area is somewhat cloud-spread, it is too sparse and contains a large number of obvious outliers and unrealistic point cloud depressions. This area needs to be eliminated, otherwise it will produce huge errors. The method can make the multi-angle point cloud models complement each other, as shown in Figure 2(d), so that the model as a whole has a high degree of credibility.

To carry out the point cloud model flattening, it is necessary to determine the relative spatial position of the human body point cloud model participating in the flattening. Since the angle of the person to be tested relative to the depth camera has been determined during the data collection process, only the body point is needed in the process of flattening[7][8]. The cloud model is displaced. The displacement process can be automated by referring to the human skeleton point data provided by Kinect. The front, side, and back point clouds acquired by Kinect contain bone point data.
The specific flattening process is shown in Figure 3. In Figure 3(a), the back point cloud model is rotated 180° along the y axis, so that the front point cloud faces the z-axis negative direction, and the back point cloud faces the z-axis positive direction. Refer to the Kinect skeleton point. The neck point and the midpoint of the spine keep the z-coordinates of the two points before and after, and translate the back point cloud in the y-x plane, so that the distance between the corresponding neck point of the two point clouds and the midpoint of the spine is the smallest, Align the two human body point cloud models before and after. The point cloud in the lower part of Figure 4(b) is the top view of the side point cloud waist. The calculation of the waist data acquisition of the three point cloud data is as follows:

Set the y coordinate value of the midpoint of the spine to $Y_{\text{Mid}}$, the y coordinate value of the base point of the spine is $Y_{\text{Base}}$. The y-axis coordinate range of the waist data is:

$$[(Y_{\text{Mid}} - Y_{\text{Base}}) \times 0.35 + Y_{\text{Base}}, (Y_{\text{Mid}} - Y_{\text{Base}}) \times 0.45 + Y_{\text{Base}}]$$ (1)

The waist data of the side point cloud can be used to determine the position of the two group of point cloud data in the z direction, and the side point cloud data is rotated by 90° along the y axis, and the maximum z coordinate and the minimum z coordinate of the side point cloud waist are set. Set the difference as $\Delta Z_{\text{side}}$, the minimum z coordinate of the front point cloud model as $Z_{\text{min}}$, the maximum z coordinate of the back point cloud as $Z_{\text{max}}$, by modifying the z coordinate of the back point cloud to translate the point cloud of back to achieve $Z_{\text{max}} - Z_{\text{min}} = \Delta Z_{\text{side}}$. At this time, the thickness of the human body can be determined, and the two point clouds have been positioned.

The positioning idea of the side point cloud model is similar to that of the front and back point cloud, and the x coordinate minimum of the front point cloud data $X_{\text{Positive min}}$. Determine the lateral edge of the human body and change the x coordinate of the lateral point cloud so that the x coordinate of the lateral point cloud is the minimum $X_{\text{side min}}$ versus $X_{\text{Positive min}}$. Equivalent. The scheme of this paper considers that the human body is symmetrical, so the side cloud of the human body on the other side is obtained by copying and mirroring. The point cloud model completed by the stitching is shown in Figure 4(c).

For the convenience of data acquisition of the body part, the limb data can be cut with reference to the bone point data to complete the capture of the region of interest, and the cropping result is shown in Figure 4(d). Figure 4(e) shows the waist point screened by the waist data acquisition method. Cloud data, at this time, the data collection work of waist circumference calculation has been completed.

4. Curve fitting

4.1 Fitting method
Considering the measurement of the waist circumference, since the extracted point cloud data is discrete, it is impossible to use a specific plane to intercept the contour of the waist.

In this paper, the point cloud data is sampled by using a "box" with a certain thickness to obtain point cloud data that can describe the waist contour, as shown in Figure 4(a). The human’s waist is parallel to the horizontal plane, so zero the y-axis data of point cloud inside the box to obtain the projection of the lumbar point cloud data in the x-z plane, and the projection is shown in the point cloud in Figure 4(b). At this time, the waist data has been converted into two-dimensional discrete data. Since the waist profile is a regular closed curve, the scheme chooses to divide the curve from the slope infinity to form the upper and lower function curves. The curve fitting method of Matlab is used to obtain the two parts of the waist contour before and after the contour. Because with the high enough order polynomial we can fit the curve of any shape, so we choose to use a polynomial for curve fitting. The 6th-order polynomial can keep the order of the experiment while maintaining the accuracy of the experiment, so the polynomial order is set to 6th order.

4.2 Fitting results
The curve fitting curve 1 (Figure 4(c)) and curve 2 (Figure 4(d)) respectively correspond to the waist curve behind the human body and the waist curve in front.

Fit curve equation:

\[ y = f(x) = p_1x^6 + p_2x^5 + p_3x^4 + p_4x^3 + p_5x^2 + p_6x + p_7 \]  

(2)

Coefficient parameter

| curve   | $p_1$ | $p_2$ | $p_3$ | $p_4$ | $p_5$ | $p_6$ | $p_7$ | x value          |
|---------|-------|-------|-------|-------|-------|-------|-------|------------------|
| Curve 1 | -5102 | 1560  | -17.15 | -34.5 | -0.9664 | 0.4314 | 2.114 | (-0.15,0.23)     |
| Curve 2 | 165   | 75.93 | -13.13 | 1.022 | 4.981 | -0.4592 | 1.8   | (-0.14,0.2)      |

Solving the length of two curves by integrating \( l_1 \) versus \( l_2 \) The upper and lower limits of the integral are consistent with the x-coordinate range of the curve, and the range of values of x refers to the last column of table x.

\[ l = \int_{a}^{b} (1 + [f'(x)]^2) \frac{1}{2} dx \]  

(3)

The result of the solution:

\[ l_1 = 0.5702m, \quad l_2 = 0.4754m \]  

(4)

The length of the two curves is summed to obtain the length of the waist measured this time \( l \):

\[ l = l_1 + l_2 = 1.0456m \]  

(5)

The length of the waist measured by the traditional measuring method is 103.0cm. Considering the factors such as clothes folds and bulges, the measurement results are within the acceptance range of this plan.
5. Verification and error analysis
In order to ensure the feasibility of this paper, this paper also carried out a confirmatory experiment on
the scheme of this paper. The experiment was carried out in two ways, measuring the same
measurement object multiple times, and measuring different measurement objects.

5.1 Multiple measurements for the same object
In this paper, the waistline data measured by the traditional scheme is regarded as the true value of the
measured data. On this basis, more measurements are made on the measuring object with a waist
length of 103.0 cm. The measurement results and errors are shown in Table 2.
The true value of the measurement object is X, the measurement value is x, and the absolute error D of
the measurement result is defined as:
\[ D = |X - x| \] (6)
The relative error Er is defined as:
\[ Er = \frac{D}{x} \] (7)
For the total error of the data of this group, it is represented by the arithmetic mean error d, and the
measurement result is \( x \). The number of measurements is n, and the arithmetic mean error is defined as:
\[ d = \frac{\sum |x - x_i|}{n} \] (8)
The relative average deviation is calculated as:
\[ \frac{d}{x} \times 100\% \] (9)
The relative average deviation of the scheme obtained from the measurement results of this group
is 1.2%, and the maximum error is 2.83%.

| Measurements | Absolute error (d) | Relative error (Er) | Measurements | Absolute error (d) | Relative error (Er) |
|--------------|-------------------|-------------------|--------------|-------------------|-------------------|
| 103.47       | 0.47              | 0.46%             | 104.12       | 1.12              | 1.09%             |
| 104.56       | 1.56              | 1.51%             | 105.03       | 2.03              | 1.97%             |
| 102.87       | 0.13              | 0.13%             | 104.56       | 1.56              | 1.51%             |
| 105.15       | 2.15              | 2.09%             | 103.14       | 0.14              | 0.14%             |
| 103.21       | 0.21              | 0.20%             | 103.72       | 0.72              | 0.70%             |
| 104.43       | 1.43              | 1.39%             | 103.67       | 0.67              | 0.65%             |
| 104.11       | 1.11              | 1.08%             | 105.92       | 2.92              | 2.83%             |
| 103.86       | 0.86              | 0.83%             | 104.49       | 1.49              | 1.45%             |
| 103.98       | 0.98              | 0.95%             | 105.91       | 2.91              | 2.83%             |
| 104.34       | 1.34              | 1.30%             | 104.07       | 1.07              | 1.04%             |

5.2 Measurement data for different measurement objects
In view of the fact that the subject of this study focuses on the phenomenon of obesity, several
volunteers with normal body size are measured. The specific measurement data are shown in Table 3.
It can be seen from the experimental data that the measurement error can be kept within 3% when
the measurement object with special body shape and the normal measurement object are measured.
The experimental results are in line with expectations.
Table 3 Measurement results of different measurement objects

| Truth Measurements | Absolut error (d) | Relative error (Er) | Truth Measurements | Absolut error (d) | Relative error (Er) |
|--------------------|------------------|---------------------|--------------------|------------------|---------------------|
| 68.5               | 69.53            | 1.03                | 1.50%              | 82.2             | 83.76              | 1.56                | 1.90%              |
| 72.5               | 74.12            | 1.62                | 2.23%              | 65.5             | 66.13              | 0.63                | 0.96%              |
| 63                 | 63.09            | 0.09                | 0.14%              | 67               | 67.76              | 0.76                | 1.13%              |
| 75.2               | 76.93            | 1.73                | 2.30%              | 74.5             | 76.32              | 1.82                | 2.44%              |
| 73                 | 73.64            | 0.64                | 0.88%              | 75.5             | 75.86              | 0.36                | 0.48%              |

6. Conclusion
In this paper, the scheme of fast 3D body measurement is realized by means of point cloud stitching and curve fitting. The stitching scheme is intuitive and feasible by means of the somatosensory function of Kinect. The curve of the waist contour is obtained by the point cloud data, and the curve is fitted to the scatter point. The integral is used to solve the length of the curve segment, and the result is in line with the actual measurement requirements. In addition to the waist circumference, the flattening scheme of this paper can also be used to measure the chest circumference and the leg circumference. However, due to the spatial positional relationship between the placement of the Kinect and the measurement object, different actions of the measurement object and the deformation of the arm causes the arm circumference of the object to be tested to be unable to be accurately measured. The interference of the hair of the object to be tested on the infrared ranging causes the measurement of the head circumference of the object to be accurately measured. etc. In general, the solution in this paper requires lower equipment cost and acquires high efficiency to obtain relatively accurate measurement data is a fast non-contact 3D anthropometric method.

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