Human Body Shape Imaging System and Its Application to Japanese Kimono Design

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Abstract - A yukata is a type of traditional Japanese clothing. An alignment of its texture pattern is an important factor of the yukata design. Three-dimensional display of the designed yukata becomes necessary for designers to make sure whether the alignment of the texture pattern satisfies wearer's taste or not. In this paper, we describe about a three-dimensional display algorithm of the yukata. At first, we developed an algorithm to measure a shape information of the wearer's body. Secondly, we developed an algorithm to map the texture pattern of the yukata on the wearer's body. Experimental results show that three-dimensional display of the yukata is useful for the designer to evaluate the result of the texture alignment.

I. INTRODUCTION

A yukata is a type of traditional Japanese clothing[1]. An alignment of its texture pattern is an important factor of the yukata design[2]. We have developed a CAD system for Japanese kimono and the measurement system for the wearer's body shape[3],[4],[5],[6]. The human body shape is measured by the stereovision method. In the measurement of the wearer's body shape, a cross pattern is projected to the body surface of the wearer at the constant intervals. The distances between four crossing points of a cross pattern and the camera are calculated by the stereovision method[6].

B. Way of wearing the yukata

The yukata consists of several parts; a right body, a left body, a right sleeve, a left sleeve, a right overlap, a left overlap and a collar. Three data of the wearer, that is, height A, hip B and shoulder plus sleeve length C are measured. The shoulder plus sleeve length is the length from the wrist to the base of the neck when the wearer horizontally stretches an arm. Fig. 3 shows the way of wearing the yukata. At first, the wearer adjust the yukata to the back center of the wearer as shown in

II. METHODS

A. Measurement system for the wearer's body shape

We developed the measurement system for the wearer's body shape as shown in Fig. 1. The measurement system consists of two CCD cameras, a LCD (Liquid Crystal Display) projector and a computer. To measure the wearer's body shape, a color cross pattern as shown in Fig. 2 are given to the body surface of the wearer at the constant intervals. The crossing points of the cross pattern on the wearer are taken by two CCD cameras that are placed in parallel to the measurement system. The distances between four crossing points of a cross pattern and the camera are calculated by the stereovision method[6].
Fig. 3 a). Secondarily, the height of the hem is adjusted to the wearer's ankle as shown in Fig. 3 b) and Fig. 3 c). The body of the yukata is fixed at the wearer's waist. Finally, the yukata cloth is folded over at the waist so that the shoulder line of the yukata is fitted to the wearer's shoulder as shown in Fig. 3 d). It is clear that the back center, the left ankle, the right ankle, the ridge of the shoulder becomes the corresponding points between the wearer's body and the yukata. We decide the corresponding points for the left part of the yukata. The point S1 is the back of the neck, the point S2 is the left of the neck, the point S3 is the left end of the shoulder, the point T2 is the left ankle and the point T4 is the right ankle. The folded area is called a tuck. The tuck makes her look tall. We set the corresponding points U1, U2 and U4 on the tuck line.

C. Shape information of the wearer's body

Fig. 4 shows a basic shape of the wearer's body approximated by a cylinder. The height of the cylinder is equal to the body length that is derived as 0.83 A. The contour length of the ellipse is equal to the wearer's hip measurement size B. In this figure, the longer axis of ellipse is twice as length as the shorter axis.

The wearer's body shape is measured by the above mentioned measurement system. The basic shape of the wearer's body is replaced by the shape information of the measurement data. Fig. 5 shows an interpolation method of the wearer's body data. The point e(x,y,z) shows a point of the basic shape of the wearer's body. The value y can be derived by the wearer's body data at the points c1, c2, c3 and c4. According to the bilinear interpolation, the value y is approximated by the following equation.

\[ y = \frac{y_1}{d_1} + \frac{y_2}{d_2} + \frac{y_3}{d_3} + \frac{y_4}{d_4} \]

where, the y1, y2, y3, and y4 are the values of the c1, c2, c3 and c4 in y axis, and d1, d2, d3, and d4 are the distances that are near to the point e in x-z plane. By this interpolation, the wearer's front body shape such as a breast is determined three-dimensionally.

D. Algorithm of displaying the texture pattern of the yukata

The algorithm of displaying the texture pattern of the yukata is as follows. The texture of the yukata cloth is mapped to the wearer's body.
Fig. 6 shows the cutting pattern of the left body. The yukata cloth is a rectangle. The body size of the yukata is determined by the traditional rule of making a yukata. For example, the position of the point S1 is given by

\[
\begin{align*}
    u &= \frac{1}{2} + \frac{1}{2} B + 7 + 2 + 1 \\
    v &= \frac{A + 2}{2}
\end{align*}
\]

where, \(\frac{1}{2} + \frac{1}{2} B + 7 + 2 + 1\) is the width of the left body and \(A\) is the length of the left body.

A cutting pattern of the left body is divided to the two parts at a line S1 S2 S3 S4. One is a front part of the left body, and the other is a back point of the left body.

Fig. 7 shows the development of the left part of the yukata. When wearing the yukata, the points S1, U1, T2, T4, ..., U4 in Fig. 6 are coincided with the points S1, U1, ..., U4 in Fig. 3, respectively. And, the points such as S1, S2, and S3 are placed on the shoulder line and the points such as T1, T2, T3 and T4 placed on the hem. When women wear a yukata, they fold the yukata cloth at the waist. The tuck area becomes necessary for folding. Considering the tuck, the wearer's yukata can be divided into upper and lower parts. Usually, the length from the hem of the yukata to the line U4', U3', U2', and U1' of the lower tuck is \(\frac{A}{2} + 3\). The length of the tuck area, that is, the width between points U1 and U1' is about 20cm. And the width \(h\) is about 0.33A-23. The point U1 and U1' becomes the same point in the wearer's body, since the tuck area is folded over at the waist.

Fig. 8 shows the three-dimensional female body shape obtained by imaging. The yukata of the left body is folded over at the wearer's shoulder. In Fig. 8 a), a curve S1 S2 represents a neck line, which the point S1 is at the shoulder and the point S2 is at the neck side. This curve corresponds to the line S1 S2 of the Fig. 6 and Fig. 8, respectively. In Fig. 8b), a curve S2 S3 passes through the front neck side point S2 and the shoulder.
end point S3. A curve S2 S3 of Fig.8 b) corresponds to the line S2 S3 of Fig.6 and Fig.7. The width of a line passing through the points S1, S2, S3 and S4 is \( \frac{1}{2}(\frac{18}{7})^{1/2} \) as shown in Fig.6. Usually, a length w between points S3 and S4 is about 20cm. The line S3 U2 T2 shows a line of the left body side. Thus, typical points of the left part of the human body can be mapped on the yukata cloth. Three-dimensional position of grid points in Fig.8 b) is measured by stereo imaging and calculated by above mentioned bilinear interpolation. On the left side of the body, a line S3 U2 is divided at a constant interval. In a similarly way, the tack line U2 U3 is divided to points and the positions of those points are three dimensionally determined.

Fig. 9 shows the yukata cloth of the left front body. At first, 4 points between the point U2 and the point U3 in Fig.8 b) are chosen on the line U2 U3. Secondarily, four lines that are parallel to v axis and pass through these 4 points are drawn. Thirdly, three points between the point S3 and the point U2 are chosen as shown in Fig.8 b). At point \( \alpha \) of Fig.8 b), the three dimensional distance D between \( \alpha \) and \( \beta \) is measured by stereo imaging. In Fig.9, the point \( \alpha \) is determined so that two dimensional distance between \( \alpha \) and \( \beta \) becomes D. In this way, three-dimensional points in Fig.8 b) are placed to the two-dimensional points in Fig.9. In similar way, the grid points of Fig.8 b) are placed on the texture pattern of the yukata as shown in Fig.9.

Fig.10 shows the shape information of the wearer's body. The texture pattern of the yukata in Fig.9 is mapped on to this wearer's body. Thus, the yukata can be displayed as a group of the triangle texture patterns.

III. RESULTS

We describe about the result of three-dimensional display of the yukata for a female student who is 163 cm in height, 68 cm in the shoulder plus sleeve length and 88 cm in the hip. The height of the cylinder that is shown in Fig. 4 is 135.3cm. And, the long axis of the ellipse is 36.4cm, and the short axis is 18.2cm, respectively. The shape of the student's upper body was obtained as shown in Fig. 11. She chose a yukata cloth with flower patterns. The flower pattern is a kind of the stencil pattern. The student designs her yukata using a CAD system we have developed as shown in Fig.12. Fig. 13 shows the three-dimensional display of the designed yukata, which the texture pattern of the designed yukata is mapped on the shape information of the wearer's body shown in Fig.10. The student could confirm the texture alignments whether the designed yukata fits for her taste from all angles. The retry of the design is possible if she isn't satisfied with the designed yukata. The three-dimensional display of the yukata could assist her to confirm the texture alignments and she can decide to make the yukata, which fitted for her taste.
Fig. 11 Wearer's body shape.

Fig. 12 Designed yukata.

a) Front view  b) Rear view

Fig. 13 Three dimensional display of the yukata.

IV. CONCLUSIONS

In this study, we developed a human body shape imaging system and a method to display the wearing condition of the yukata three-dimensionally. The designer may evaluate the designed yukata whether it will satisfy for wearer's taste or not, before sawing the yukata.