Measurement of Planar Clothes Using Level Set Method for Automatic Inspection

Kyohei Takahashi, Gakuto Masuyama, Kazunori Umeda
Course of Precision Engineering
Chuo University
Tokyo, Japan
umeda@mech.chuo-u.ac.jp

Toshiaki Osada, Kazuo Furushima
Fashion Cloth Furushima
Saitama, Japan

***Abstract*— This paper presents an image processing system for measurement of flat clothes such as T-shirts automatically to make clothes inspection process more effective. The proposed system uses a camera arranged vertical to an inspection stand and captures images of clothes. First, the contours of clothes in images are extracted by Level Set Method. The proposed system uses edge information in extracting the contours. The inspection stand's color is set to be different from the subject of measurement so that edge information can be obtained easily. Second, straight or curve lines are fitted to the contours. In the fitting, regions near the intersection points of the contours are eliminated, so that the effect of local wrinkle at armpit by flexibility of clothes is reduced. Inspection points are detected as intersection of fitted lines. Finally, the dimensions of clothes are calculated by three-dimensional Euclidean distance between inspection points.**

Keywords*— *image processing; Level Set Method; measurement of clothes; automatic inspection

I. INTRODUCTION

There are many processes of manufacturing clothes. One of them is inspection, which is the process that decides whether color, size, etc. of the clothes are suitable for standards. This process is being done by inspectors as shown in Fig. 1. However, the inspection of several items such as size and color unevenness manually is inefficient, and labor cost for the manual inspection is becoming a big issue.

Recently, there are several works that measure clothes by using sensors for various purposes. Hou and Sahari proposed a system that recognizes the shape of clothes using edge and corner information for operation by robots [1]. Nakamura et al. proposed a system that calculates the size of the subject's clothes using Kinect for a virtual fitting room [2]. However, they are not aimed at measuring the dimensions of clothes precisely. Furthermore, it is difficult to introduce these systems in current workspaces as shown in Fig. 1.

Fig. 1. Traditional inspection of clothes

This paper proposes a system for automatic inspection of clothes using a camera set on the celling. The system automatically measures dimensions of several parts of flat clothes such as T-shirts that are placed on the inspection stand.

II. SYSTEM FOR AUTOMATIC INSPECTION OF CLOTHES

We assume that intrinsic parameters of the camera and relationship between the image coordinate system and the world coordinate system are known beforehand by camera calibration procedures. Clothes to be measured are set on the inspection stand by an inspector. The inspection stand's color is set to be different from the target clothes so that edge information can be obtained easily.

The flow of the proposed method is shown in Fig. 2. First, the contours of clothes are extracted from the image of the camera using Level Set Method (LSM) [3][4]. Second, the points of contours are classified into parts of clothes such as sleeves or hems. Third, the outliers classified into the parts are removed by RANSAC [5]. Fourth, straight or curve lines are

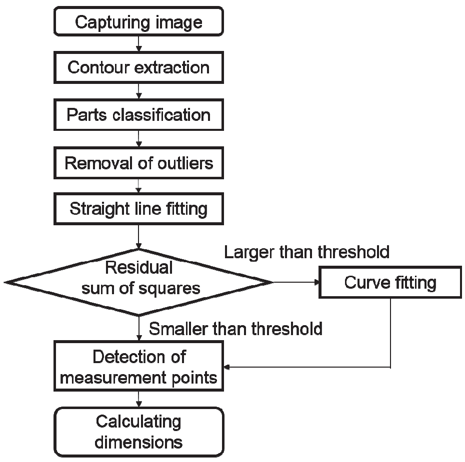


Fig. 2. Flow of proposed method

Fig. 3. Input image

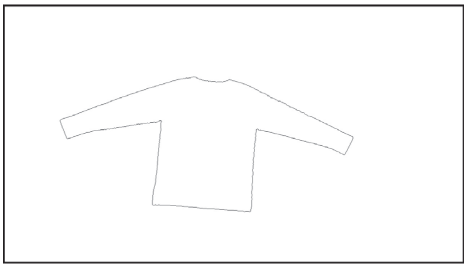


Fig. 4. Extracted contour

fitted to the contour points and inspection points are detected as intersection of the lines. Three-dimensional (3D) coordinates of each inspection point in the world coordinate system are obtained by applying the homography matrix to the two-dimensional image coordinates of the point. Finally, the dimensions of clothes are calculated by obtaining 3D Euclidean distances of the inspection points.

A. Extraction of contours using Level Set Method

Contours of clothes are extracted using differences of image intensities between the inspection stand and clothes. We adopt LSM, which is a typical method to extract contours flexibly. First, an initial contour is set so that it contains the whole inspection stand. Then the contour is converged to fit the shape of the clothes. The speed of contour point (i, j) is given by

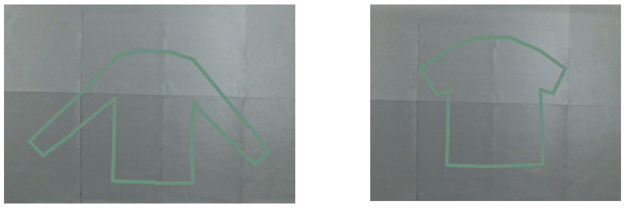
$$F_{i,j} = k_{I,i,j}(a - b\kappa_{i,j}) \tag{1}$$

where a and b are constants, $\kappa_{i,j}$ is the curvature of the auxiliary function. $k_{I,i,j}$ is the intensity gradient that is given as

$$k_{I,i,j} = \frac{1}{1 + \left|\nabla G \otimes I(i,j)\right|^{\gamma}} \tag{2}$$

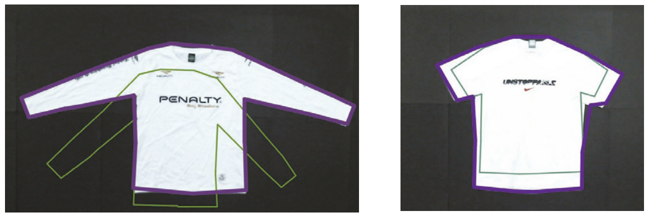
where I is the intensity value at (i, j), G is a gain, and γ is a constant. The speed of contour point becomes large when intensity gradient is small, and it converges to zero in accordance with the increase of intensity gradient.

Fig. 3 shows an image captured using the constructed system described later, and Fig 4 shows the contour extracted from Fig. 3.



(a) Long sleeve (b) Short sleeve

Fig. 5. Reference models



(a) Long sleeve (b) Short sleeve

Fig. 6. Models after transformation. Green: original, purple: transformed.

B. Classification of the contour points

The extracted contour points are classified into the parts of the clothes, i.e., neck, shoulder, sleeve, hem, and armpit. When clothes are manufactured, design models or CAD models that contain shape of the clothes are given. The shape of the inspected clothes is similar to that of the models. Therefore, we use a reference shape model that imitates these models as shown in Fig. 5 for the classification. First, rotation, translation, and scale change are obtained from the relationship between the reference model and the extracted contours. Additionally, the difference of slope of sleeves from the reference model is obtained using the contour points around the shoulder in case the garment has long sleeves. In this way, the variation that the inspector puts the clothes on the inspection stand can be compensated. The reference model is transformed using the obtained parameters. Second, the closest contour point from the transformed model point is aligned as the new model point. As a result, the shape error between the model and the measured clothes is reduced. Finally, the contour points are classified into each part of clothes using the transformed model that is shown in purple lines in Fig. 6. Each contour point is classified to a part when the distance between the contour point and the line of the part is small.

C. Straight or curve line fitting

First, RANSAC is applied to each classified point group to remove outliers. Furthermore, as the points near the inspection point is susceptible to local wrinkles and deformation, they are also removed as outliers. Next, a straight line is fitted to the point group from which the outliers are removed. If the sum of squared residuals is greater than a certain threshold, a quadratic and then cubic curve is fitted to the group of points.

Fig. 7 shows an example of classification of contour points after removal of outliers. Fig. 8 shows the fitted lines to the neck and shoulder parts. A straight line is fitted the shoulder parts, and a quadratic curve is fitted to the neck part.

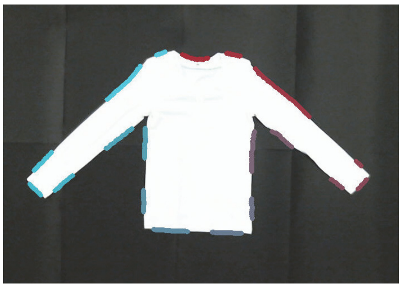


Fig. 7. Classification of contour points

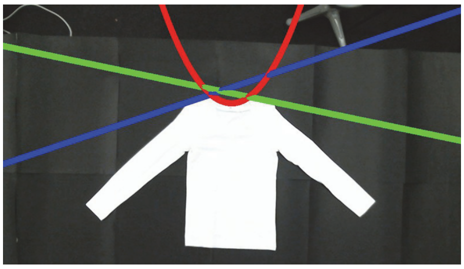


Fig. 8. Line fitting to neck and shoulder parts

D. Detection of inspection points and measurement of dimensions

Intersection points of the obtained lines are calculated and the points are used as inspection points. The dimension is calculated as the Euclidean distance between the designated dimension points in the world coordinate system. The relationship between the position of the inspection point (i, j) in the image coordinate system and the position $(X_w, Y_w, 0)$ in the world coordinate system is given by a homography matrix as

$$\begin{bmatrix} X_W \\ Y_W \\ 1 \end{bmatrix} \sim \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & 1 \end{bmatrix} \begin{bmatrix} i \\ j \\ 1 \end{bmatrix} \quad (3)$$

where "~" represents the equivalence as homogeneous coordinates. The homography matrix is obtained by a prior calibration procedure. The world coordinate system is set so that the surface of the inspection stand on which the inspected garment is placed satisfies Z_w=0. Note that (3) can be rewritten as follows.

$$\begin{cases} X_W = \dfrac{h_{11}i + h_{12}j + h_{13}}{h_{31}i + h_{32}j + 1} \\ Y_W = \dfrac{h_{21}i + h_{22}j + h_{23}}{h_{31}i + h_{32}j + 1} \end{cases} \quad (4)$$

III. EXPERIMENT

A. Experimental conditions

We executed experiments to verify the effectiveness of the proposed method. The experimental environment is shown in

Fig. 9. Experimental environment

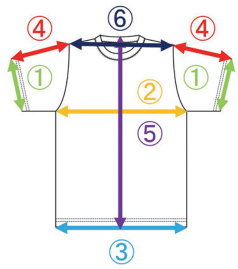


Fig. 10. Target dimensions

Fig. 9. A Logicool HD Webcam C615 is fixed to the ceiling. The height from the floor to the inspection stand is 0.69 m and the height from the inspection stand to the camera is 1.87 m. Target dimensions are cuff length, bust, hem length, sleeve length, clothes length, and shoulder width. Reference position of each dimension is shown in Fig. 10. Name of each dimension is shown in Table 1. The target objects were two long sleeve T-shirts and two short sleeve T-shirts. When the color of clothes is deep, the garment was set on a white inspection stand, and when not so, a black sheet was set on the inspection stand and the garment was set on the sheet.

Measurement was done 10 times for each T-shirt. The T-shirt was removed and set again at each measurement. The average of five measurements obtained in advance using a tape measure was used as the true value. RMS errors were calculated for evaluation. The required accuracy for current manual inspection is ±3% in cuff width and ±1.0 cm in other dimensions.

B. Experiment results

Fig. 11 shows examples of detecting inspection points. It is shown that inspection points are properly detected except the

TABLE I. KINDS OF DIMENSIONS

Number	Names	Details
①	Cuff width	Length of cuffs
②	Bust	Length of armpits
③	Hem width	Both ends of hem
④	Sleeve length	Shoulder to cuff
⑤	Clothes length	Neck to bottom
⑥	Shoulder width	Both ends of shoulder

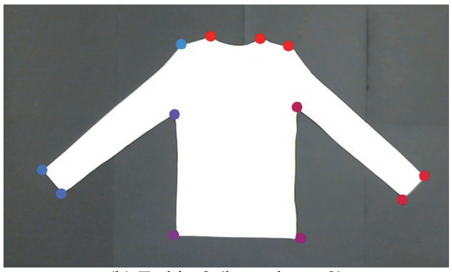
points at the shoulders in Fig. 11 (a). Table 2 shows the results of dimensional measurements. Each pair of values in Table 2 represents the true value / RMS error, whose unit is cm. It is shown that cuff length and hem length are measured stably. On the other hand, RMS error of bust, sleeve length, and shoulder width are relatively large compared to other dimensions. The reason of large error of Bust is thought as follows. As wrinkles and deformation are likely to occur in the clothes around armpits, distortion occurred as shown in Fig. 12, and as a result, line-fitting errors became large. Another reason is that the side stitches that should be detected are hidden when the clothes were set on the stand. On the contrary, the reason of the large errors for the sleeve length and the shoulder width is the detection failure of the inspection points of both shoulders. This detection failure is thought to be due to the fact that the contours from the neck of the clothes to the sleeve tip became nearly straight and thus the point of intersection of the contour line of the shoulder and the sleeve could not be determined precisely. The proposed method detects the inspection points of shoulders from the intersection of lines fitted to the sleeve and to the points between the neck and the shoulder. Therefore, it is thought to be difficult to detect inspection points at the shoulders in clothes whose shape is straight from the neck to the sleeve as shown in Fig. 11 (a)

IV. CONCLUSION AND FUTURE WORKS

This paper proposed a system for automatic inspection of the clothes. The system measures dimensions of planar clothes like T-shirts by extracting contours of the clothes, classifying the contour points to parts, fitting lines to the contour points of each part, obtaining inspection points by intersection of lines, and calculating 3D Euclidean distances between the inspection points. From the evaluation experiments, it is shown that most dimensions can be measured with sufficient measurement accuracy. At the same time, it is shown that detection of the inspection points of the shoulders is difficult and causes large errors for the clothes with straight line from the neck to the sleeve.

In future works, we will try to construct a system that can detect the inspection points of shoulders more precisely using a different approach. And the speed-up of the system is also an important issue. Extraction of contours using LSM that spends nearly 5 s is especially time consuming and should be fastened or replaced. Furthermore, we will consider a system that can measure other clothes such as pants and jackets.

(a) T-shirt 1 (long sleeve 1)



(b) T-shirt 2 (long sleeve 2)

(c) T-shirt 3 (short sleeve 1)

(d) T-shirt 4 (short sleeve 2)

Fig. 11. Detection of inspection points

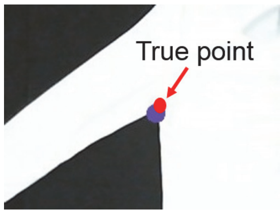


Fig. 12. Detection failure of left armpit

REFERENCES

[1] Y. Hou and K. Sahari, "Identifying corners of clothes using image processing method," 2010 International Conference on Intelligent and Advanced Systems (ICIAS), 2010.

[2] R. Nakamura, M. Izutsu and S. Hatakeyama, "Estimation method of clothes size for virtual fitting room with kinect sensor," 2013 IEEE International Conference on Systems, Man, and Cybernetics, pp.3733-3738, 2013.

[3] J. Sethian, Level Set Method, 1st ed., Cambridge University Press, 1996.

[4] Y. Iwashita, R. Kurazume, T. Hasegawa, and K. Hara, "Robust motion capture system against target occlusion using fast level set method," Proc. of ICRA, pp.168-174, 2006.

[5] M. Fischler and R. Bolles, "Random Sample Consensus: A paradigm for model fitting with apphcatlons to image analysis and automated cartography," Communications of the ACM, Vol. 24, No. 6, 1981.

TABLE II. RESULTS OF MEASUREMENTS (TRUE VALUE / RMS ERROR, UNIT : cm)

	Cuff width		Bust	Hem width	Sleeve length		Clothes length	Shoulder width
	Left	Right			Left	Right		
T-shirt 1	10.18 / 0.20	10.34 / 0.35	50.22 / 1.28	51.90 / 0.65	60.58 / 2.07	60.82 / 6.96	67.82 / 0.24	42.86 / 12.96
T-shirt 2	9.12 / 0.54	9.12 / 0.33	37.86 / 0.91	37.56 / 1.11	58.30 / 0.75	57.66 / 0.80	60.74 / 0.51	35.78 / 4.16
T-shirt 3	16.66 / 1.10	16.72 / 0.75	48.96 / 0.82	48.62 / 0.47	17.58 / 3.56	17.94 / 4.13	68.54 / 1.56	51.36 / 9.81
T-shirt 4	19.24 / 0.90	19.36 / 0.95	52.64 / 1.58	52.42 / 0.64	20.56 / 1.62	21.04 / 3.65	70.96 / 1.87	51.80 / 2.42