Rapid Detection Method for Fabric Defects Based on Machine Vision

Yao Rong, Dong He, Yuchi Lin
State Key Laboratory of Precision Measuring Technology and Instruments
Tianjin University
Tianjin, China

***Abstract*—A new detection method for the non-destructive test of fabric defects based on machine vision is proposed in this study. In the proposed method, (a) the raw image is pre-processed by figuring the contrast and intensity to a proper level, (b) candidate regions are detected using the HSI color model and dynamic binarization, (c) the characteristic line of the target is obtained by the gray weighted centroid algorithm and (d) the quality of the product is judged by the number of valid pixel in the candidate region and the separation angle calculated from the characteristic line. Taking the detection of diaper as an example, an automatic detection system is built with an industrial camera. The position of diaper elastic waist and angle of the waist label, which are the two major parameters in the test of diaper quality, are examined based on the proposed method. Experimental results indicate that this method can be applied efficiently and effectively while resolving the problem of relative weak illumination and low contrast, bringing down noises caused by wrinkle and stain, and achieving a stable online inspection.**

Keywords-machine vision; gray weighted centroid algorithm; fabric defects; image segmentation; color extraction;

I. INTRODUCTION

The defect inspection and recognition is one of the vital procedures in the inspection process of fabric products. Previously, the defect detection is manipulated by manual work, in which some major error might probably be generated, such as those quality failures caused by high labor intensity, low efficiency, manifest omission factor and restriction to the subjective factors of operators [1]. Since 1990s, the automatic detection technique of fabric products based on image processing and machine vision has been gradually replacing the manual method as the focus of the fabric defect inspection. In various industrial cases, machine vision systems have been applied to monitoring manufacturing processes [2], to look over product quality [3][4] or to arrange products or equipment [5].

In this study, a new fabric defect detection method is proposed based on machine vision and image processing. As a typical case of fabric defect detection, diaper detection utilizing the proposed method is demonstrated in the following article. On account of the large size and the complex surface situation, manual detection of infant diaper defects has long been a time-consuming task while it is still in low accuracy level and has a great chance of erroneous judgment. With the booming living standard of modern people, high quality diapers are in great demand. As a result, the quality standard of diaper manufacture has been rapidly upgraded. Moreover, since the product directly contacts skins of infants, the sanitary quality of diaper surface should also been strictly constrained i.e. stain spots on diaper surface should be limited to a negligible number. The proposed method, which sets the position of elastic waist and the angle of the waist label as the detection target, is designed according to the superincumbent principle and includes some universal algorithm in image processing, such as image segmentation, image filter and edge detection as well as a tailor-made image extraction and angle measurement algorithm. Hence, the detection systems built based on the proposed method can reach high accuracy, high response speed and good stability while reducing detection costs meanwhile. This study briefly reviews defect information of diapers and investigates the geometry model for diapers. The proposed method is elaborated by mathematical and flow chart description.

II. DEFECT INFORMATION IN INSPECTION

The important advantage of machine vision detection compared to human measurement can be summarized as greater consistency, less time requirement and much higher accuracy and resolution [6]. The higher consistency and less time-consuming of machine vision are ensured by the high degree of automation. The higher accuracy and resolution of machine vision are on the premise of a machine system and image processing algorithm with the equivalent or higher accuracy and resolution. Therefore, it is essential to establish a geometry model for diaper detection in the machine reference frame.

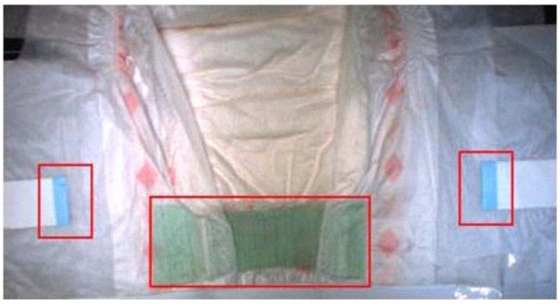

Figure 1. Overall view of a determinand diaper

The main candidate detection area of a diaper is on the surface of the single side, as illustrated in Fig.1. The middle section in green, as showed in Fig.2, is the elastic waist, which helps ameliorate the flexibility of infants, and the diaper labels with blue tags are located on both sides of the diaper, which help fix the diaper steadily on the waist of infants in case of falling-off when infants are moving around. The two major detection tasks are (a) judging the deletion or dislocation of elastic waist and (b) examining the separation angle of the diaper label. The rectangle area highlighted with red pane in Fig. 1 shows the position and overall situation of the candidate detection area.

Figure 2. Elastic waist detection area

A qualified diaper elastic waist should be in the shape of a regular curve edge quadrilateral and in the central position of the candidate detection area. The detection geometry of a diaper elastic waist can be characterized by the width and length of the candidate detection area and the valid pixel number of elastic waist N, as illustrated in Fig.3(a). When it comes across a unqualified product with a cross-border flaw, as illustrated in Fig.3(b), it could be justified by a comparison between the valid pixel number N and the threshold value T pre-set by users according to the situation of the working environment.

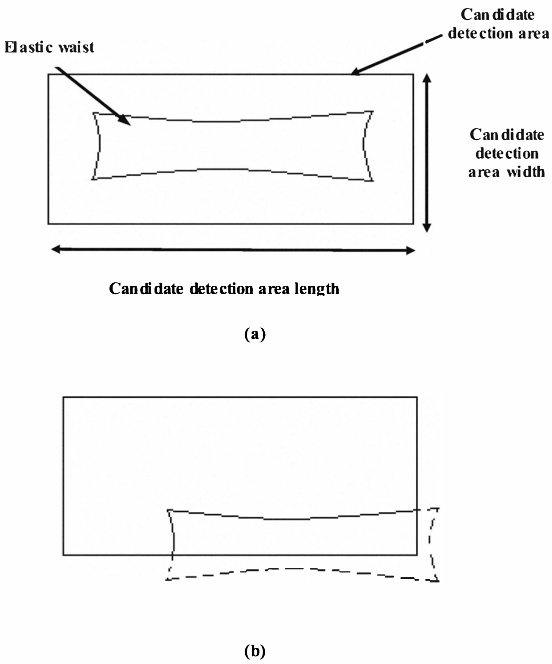

Figure 3. Definition of elastic waist geometry: (a) overall elastic waist geometry of a qualified product; (b) unqualified elastic waist due to cross-border

The detection geometry of a diaper label is mainly modeled by the separation angle between the edge of diaper label and the machine reference frame axis, as illustrated in Fig.4. The edge of a qualified diaper label should be rigidly perpendicular to the bottom axis the machine reference frame. Therefore, the separation angle should be limited to a negligible value.

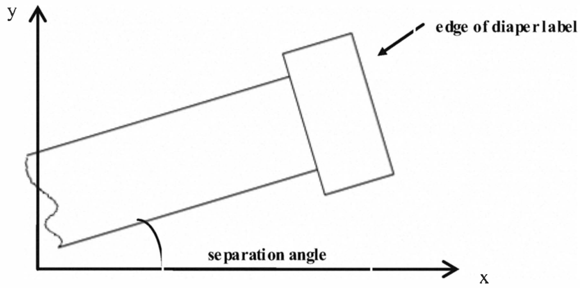

Figure 4. Definition of diaper label geometry

III. FLAW DETECTION USING MACHINE VISION AND IMAGE PROCESSING

A. Detection of elastic waist

In the proposed method, detection of elastic waist is based on color properties of diapers, shape-based verification and statistical histogram. Fig. 5 shows a schematic flow chart of the detection process.

1. Image enhancement

Since the detection environment of elastic waist is capricious, the quality of raw images cannot be guaranteed. The variation of the illuminator, the light noise generated from the environment and the pollution on the diaper surface can all conduce to the failure of detection. Image enhancement, as a vital part of preprocessing procedures, is thus in desperate need [7].

The various approaches of image enhancement in previous studies can be categorized in two classes: the direct image enhancement approaches and the indirect image enhancement approaches [8]. In the proposed method, the indirect method image histogram extension is adopted for image enhancement. Histogram extension is a technique for amplifying the distinction of foreground and background in grey-level images. It expands the contrast in either liner or non-liner approaches [9].

The hue of the raw image f(x, y) ranges from z1 to z2. The hue value g(x, y) range after the liner transform is $[z'1, z'2]$. The transfer function from f(x, y) to g(x, y) is:

$$g(x,y) = z_1' + \frac{z_2'-z_1'}{z_2-z_1}[f(x,y) - z_1] \tag{1}$$

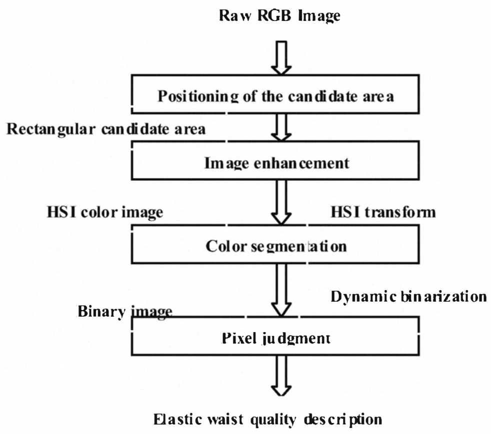

Figure 5. Scheme flow chart of elastic waist detection

Utilize the model in Equation (1) to set a configuration parameter n in (-127, 128). The new pixel hue g can be calculated according to:

$$g = \begin{cases} 0, \ f < n, n > 0 \\ 255, f > 255 - n, n > 0 \\ (f - n) \times \frac{255}{255 - 2 \times n}, \text{Otherwise} \end{cases} \quad (2)$$

Then calculate the new RGB value respectively and obtain the image with a better contrast after image enhancement, as justified in Fig.6. The image histogram method is simple to manipulate, and shows excellent performance ameliorating the image contrast [10].

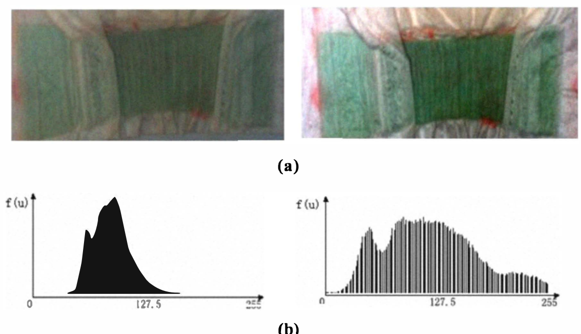

Figure 6. Image enhancement by histogram extension: (a) image view and (b) statistical histogram before and after image enhancement

Since pre-processed image is of better contrast and brightness, it is convenient to implement image segmentation in the candidate area. The proposed method extracts target image section in HSI color space.

Compared to the RGB model, color description based on the HSI model is closer to the feeling of human eyes. Moreover, the hue and saturation parameter in the HSI model is mainly determined by the absorption and reflection nature of the material and immune to the disturbance generated by the variation of illumination and viewing angle. Consequently, the HSI model can be applied to getting rid of the luminance component from the image. Since the images taken in the industrial detection site of fabric manufacture are frequently accompanied with disturbance and noise, such as stain spots on the surface, wrinkle of the fabrics and noise light generated by diffuse and reflection on the surface, the image segmentation and color extraction in the HSI space would efficiently and effectively eliminate the noise and disturbance from the background and attain a better extraction image.

The following equation shows the mathematical transform from the RGB space to the HSI space:

$$\begin{cases} I = \dfrac{R+G+B}{3} \\ H = \dfrac{1}{360}\left[90 - \arctan\left(F/\sqrt{3}\right) + \{0, G > B; 180, G < B\}\right] \\ S = 1 - \dfrac{\min(R,G,B)}{I} \\ F = \dfrac{2R - G - B}{G - B} \end{cases} \quad (3)$$

In the candidate area, the hue of elastic waist is significantly more focused and of higher saturation compared to the background. Combining the hue and saturation feature of the pre-processed image, the target image can be extracted effectively.

2. Pixel judgment

In the final step, the method of dynamic binarizaiton based on the maximal variable ratio [11] is adopted to transform the image into a binary one. The valid pixel number of the pre-processed area is obtained through scanning and the number is compared with the threshold value pre-set by users to judge the quality of the elastic waist.

B. Detection of diaper label position

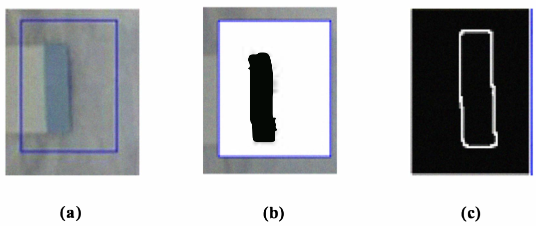

Figure 7. Image pre-processing: (a) raw image (b) extracted image after binarization and (c) edge detection using Sobel operator

The detection task for the diaper label position is mainly centralized on examining the separation angle between the diaper label and the reference frame. Since the contrast between the blue label and the background is not observable enough in the RGB space, the image segmentation and the extraction of the candidate label area is implemented in the HSI space. After dynamic binarization based on the maximal variable ratio [11] and edge detection using Sobel operator [12][13], the binary image containing the label edge information is obtained. Then, image denoising based on mathematical morphology is conducted on the raw image to remove burs and noise spots on the edges [14].

One frequently used method of the online measurement of the separation angle is to implement linear fitting of the marginal points [17]. The fitting line calculated by linear fitting algorithm, such as the least square regression algorithm, is of poor stability when it is applied to the measurement of the separation angle for the reason that marginal points on only one edge of the rectangular would be taken into account in one single calculation and any noise spot and pixel fluctuation would have a significant impact on the linear equation.

In the proposed method, the measurement of the separation angle between the diaper label and the reference frame is based on the gray weighted centroid algorithm. The gray weighted centroid algorithm is the method for sub-pixel subdivision and weighted centroid positioning of image features, which fits in the cases when the image is of a symmetry distribution and high gray value [15][16]. The binary edge image after pre-processed procedures is in the shape of a regular rectangular with few noise spot. Therefore, it is feasible to apply the gray weighted centroid algorithm to the measurement of the separation angle between the diaper label and the reference frame.

The gray weighted centroid algorithm is derived from the centroid calculation of a geometrical figure. The gray weighted centroid is defined as the centroid of a binarized image after weighting by gray scale.

The gray weighted centroid $S(x_0, y_0)$ of a gray level image $I(i,j)$ can be calculated according to the equation:

$$\begin{cases} x_0 = \dfrac{m_{10}}{m_{00}} = \dfrac{\sum\limits_{(i,j)\in S} iI(i,j)}{\sum\limits_{(i,j)\in S} I(i,j)} \\ y_0 = \dfrac{m_{01}}{m_{00}} = \dfrac{\sum\limits_{(i,j)\in S} jI(i,j)}{\sum\limits_{(i,j)\in S} I(i,j)} \end{cases} \quad (4)$$

The procedures of angle calculation based on the gray weighted centroid algorithm are described as follows:

Divide the label rectangular into two congruent rectangular in the y direction;

Calculate the centroid of each rectangular according to equation (4);

The connected line of the two centroids is figured out as the characteristic line representing the obliquity of the diaper label in the machine reference angle. The angle between the characteristic line and the y axis is the pending separation angle.

Fig.8 shows a schematic description of the application of the gray weighted centroid algorithm to the label angle detection.

Compared to the marginal point linear fitting method, the gray weighted centroid algorithm method shows better performance for it significantly lowers the influence of noise spots. Due to the symmetric characteristic of the target rectangular, the calculation of the centroid cancels symmetry points on opposite sides. The centroid calculation also deals with marginal points on all sides of the rectangular which helps smooth the noise spots to a larger extend.

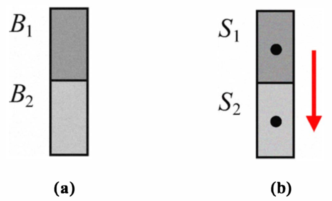

Figure 8. Schematic description of the application of the gray weighted centroid algorithm to the label angle detection

IV. Experimental Result

In order to verify the validity and efficiency of the defect detection algorithm, 1000 different diaper images are tested in ten testing groups. Since the chosen products in this experiment are carefully examined by experienced manual detection, the results of manual detection could be regarded as the exact description of the products. Table I shows the results from the contrastive detection experiment of the automatic and manual method. As a result, the concurrent defect detection method enhances the detection accuracy and the error rate of the method is limited within 0.4%.

TABLE I. Contrastive Detection Experiment Result

No.	*Numbers of qualified products by manual detection*	*Numbers of qualified products by automatic detection*	*Error rate in automatic detection*
1	*100*	*100*	*0*
2	*99*	*98*	*1%*
3	*100*	*99*	*1%*
4	*100*	*100*	*0*
5	*100*	*100*	*0*
6	*99*	*100*	*1%*
7	*100*	*100*	*0*
8	*100*	*100*	*0*
9	*100*	*99*	*1%*
10	*100*	*100*	*0*

V. Conclusion

In this study, a method for the rapid detection of fabric defects based on machine vision and image processing is proposed. The method implements image pre-processing, including image segmentation and color extraction, mainly in the HSI space rather than in the RGB space, which ensures higher stability against common disturbance, such as wrinkles and stains on the fabric surface and noise generated by surface diffuse reflection. Moreover, the application of the gray weighted centroid algorithm on the measurement of separation angle gains superiority over the common linear fitting method of marginal points. In the diaper detection system using the proposed method, the position and integrity of the elastic waist and separation angle of the waist label are examined. Experimental results of the detection system shows it has reach a rather high accuracy while addressing the problem of tardiness, low efficiency and high erroneous rate of manual detection.

REFERENCES

[1] Jiang Lei, Yin Ye-an, Chang Li−li, "An Automatic Processing Method to Inspect and Recognize Fabric Defects Based on Computer Vision Inspection," Computer and Modernization vol. 12, pp. 154–159, 2008.

[2] N. Zuech, Applying Machine Fision (New York: John Wiley & Sons,1988).

[3] W.A. Perkins, "Model-Based Vision System for industrial Parts,"IEEE Trans. on Computers (C-27, 1978), pp126-143.

[4] K. Harding, "Machine Vision Based Gaging of Manufactured Parts"Irtsion, MVA/SME quarterly (v12, n2, 1996), ppl-6.

[5] K.C. Lee, H.P. Huang, and S. S. Lu, "A Flexible Robot Inspection CellBased on Vision Image," Int7 Journal of Computer Integrated Mfg (v5,n4&5, 1992), pp310-318.

[6] Churchill, D.B. ; Bilsland, D.M. ; Cooper, T.M. "Comparison of machine vision with human measurement of seed dimensions" Transactions of the American Society of Agricultural Engineers vol. 35, pp. 61−64, 1992.

[7] Chen Lijuan,Xu Lihua "Preprocessing Algorithm of Character Image by Assembling Denoising Algorithm and Mathematical Morphology" Modern Electronic Technique, vol. 32, pp. 110--111,2009

[8] Hu Qiong, Wang Ronggui, Hu wei-wei, Yang Wan−ting, "Color image enhancement eased on histogram segmentation", Journal of Image and Graphic, vol. 8. Issue 14, 2009.

[9] Zhu Zhongqiu , Li Bin "Image enhancement algorithm based on histogram extension and its implementation" Journel of Information Technology, vol.5 2009.

[10] Zhu Huiping,Wei Fengyuan,"Discussion on the Application of Histogram Equalization inIm age Enhancement," Geomatics & spartial information technology, vol. 33, Feb. 2010

[11] El-Bassiouni, M.Y. , Charif, H.A. "Testing a null variance ratio in mixed models with zero degrees of freedom for error", Computational Statistics and Data Analysis, v 46, n 4, p 707-719, July 1, 2004

[12] Zhang, Jin-Yu, Yan Chen, Huang Xian-Xiang "Edge detection of images based on improved sobel operator and genetic algorithms", Proceedings of 2009 International Conference on Image Analysis and Signal Processing, IASP 2009, p 32-35, 2009, Proceedings of 2009 International Conference on Image Analysis and Signal Processing, IASP 2009

[13] Kanopoulos Nick, Vasanthavada Nagesh, Baker Robert L. "Design of an image edge detection filter using the Sobel operator" IEEE Journal of Solid-State Circuits, v 23, n 2, p 358-367, Apr 1988

[14] Fadili M.J., Starck J.-L., Boubchir L. "Morphological diversity and sparse image denoising" ICASSP, IEEE International Conference on Acoustics, Speech and Signal Processing - Proceedings, v 1, p I589-I592, 2007, 2007 IEEE International Conference on Acoustics, Speech and Signal Processing, ICASSP '07

[15] Changying Liu , Yinhan Gao2 , Yong Zhang "Squared gray weighted centroid algorithm based on bi-cubic interpolation" Proceedings of SPIE--The International Society for Optical Engineering, v7133, 2009, Fifth International Symposium on Instrumentation Science and Technology

[16] Tang Shengjin, Zhou Zhaofa, Guo Xiaosong, Xiao Yongchao, "Improved iteration centroid algorithm based on linear CCD light-spot location" ICEMI 2009 - Proceedings of 9th International Conference on Electronic Measurement and Instruments, p 4438-4440, 2009

[17] Bateni A. Susnar S.S., Amirfazli A., Neumann A.W. "A high-accuracy polynomial fitting approach to determine contact angles" Colloids and Surfaces A: Physicochemical and Engineering Aspects, v 219, n 1-3, p 215-231, June 19, 2003