Recognition of Object ID marks in FA process from Active Template Model

Dong-Joong Kang*, In-Mo Ahn**, Tae-Jung Lho*, Hyung-Keun An*,
Dong-Hun Yoo*, Mun-Jo Kim*

* College of Information Engineering, Tongmyong University of IT, Yongdang-dong 535, Nam-gu, Busan, Korea. Tel: 82-51-610-8361, E-mail: djkang@tmic.tit.ac.kr
** Division of Computer and Electrical Engineering, Masan College, Masan, Kyungnam, Korea. Tel: 82-55-230-1328, E-mail: imahn@masan-c.ac.kr

Abstract: This paper presents a method to segment object ID marks on poor quality images under uncontrolled lighting conditions of FA inspection process. The method is based on multiple templates and normalized gray-level correlation (NGC) method. We propose a multiple template method, called as ATM (Active Template Model) which uses combinational relation of multiple templates from model templates to match and segment several characters of the inspection images. Conventional Snakes algorithm provides a good methodology to model the functional of ATM. To increase the computation speed to segment the ID mark regions, we introduce the Dynamic Programming based algorithm. Experimental results using images from real FA environment are presented.

1. Introduction

As the manufacturing industry is being advanced, it has been increased the need of the automation for conventional inspection that are manually performed. In order to provide the visual inspection system applicable to the usual automation environment, it is necessary to develop the algorithm stable and performing reliable pattern recognition. The image segmentation as a main step to split meaningful areas from an interesting image is regarded as the most necessary and important procedure in the machine vision system. Many studies about the image segmentation have been being done so far and several results have been reported in previous works [1-5].

Conventional methods for image segmentation could be categorized to three parts such as the area based, the edge based, and the histogram based techniques [1-4]. In the area-based method, pixels with similar intensity values are considered as one area and thus consist of homogenous regions form an image. The split-and-merge algorithm stands for the area based segmentation [2]. The algorithm divides an image into fixed areas and compares intensity similarity with neighboring pixels. If those areas are thought as the same area, merge those areas and if not, splits those areas iteratively. This method could provide good results but needs high time-complexity as well. The edge-based segmentation can segment the image into contour and the inner component by using intensity discontinuity of images. In the case of any noises found, the method may follow the false edge and hence needs any additional processing.

Segmentation by histogram [4] is mainly used when the distribution of the gray level is simple. The method makes the image segmentation easy by carrying out quantization the whole image as the highest two gray level after obtaining the histogram of all gray level. Thus this method may have a good segmentation effect when the distribution of histogram is concentrated on the two gray levels that present background and object, respectively. Especially, in case of object ID inspection of the automation process, the algorithms using histogram projection and Hough transformation are general approaches [11,12]. Most of such existing algorithms may show a good result in clean image with good visualization whereas the segmentation in poor quality images may be a serious problem. Such difficulty is caused by vague distribution characteristics of image intensity, due to noise and irregular lighting condition.

This paper aims to automatically segment the character area for recognition of object ID marks under poor visualization condition. The segmentation of inspection area is pre-processing procedure for recognition and the successful execution of this task will determine the success of whole process. Under poor lighting condition, none of the image features may be detected with reliability. Thus conventional approaches such as histogram projection and image binarization become difficult to be applied.

We first try to solve the ID mark segmentation by using template matching method because many conventional and commercial machine vision systems try to solve the mark recognition from application of template matching technique. However, the method is also difficult to apply in case of poor visualization image for the reason of frequent occurrence of fault matches.

We observed usual object ID marks are not single character and a few characters are continuously written on object surface to be inspected. If we try to match only single character by conventional template matching technique, it may be fail in most cases. However, assume that *one model template* consists of two characters, then it is possible to get more increased success rate of the matching. This idea is starting point for the work in this paper.

Because the distance between any two neighboring characters of ID marks is not uniform and changeable, the functional for the variable distance has to be incorporated to a model equation. We have introduced the Snake's algorithm to object ID segmentation problem. The Snakes algorithm is called Active Contour Model because the spline curve of the Snakes actively responses to image data and attaches to strong image edges denoting object boundaries [9].

The functional to be optimized includes the distance between two neighboring characters and similarity ratio matched to each model character templates. The ATM (Active Template Model) proposed in this paper actively interacts to image data to segment successively positioned several characters in poor quality images. Dynamic programming is applied to reduce computational cost in optimization of the defined functional. The experimental results using real images of FA process are presented to show the feasibility of the proposed algorithm.

2. Active Template Model

A central preprocessing step of conventional OCR algorithm is to segment character regions from background of inspection images. However, it not easy to apply the preprocessing step in poor quality images of FA processes. For an example, Fig. 1 shows the characters images engraved on flat glass panel. Because the light permeates the transparent material like glass, visualization of the ID marks on glass is very difficult and needs careful lighting control by skilled experts. The degree of visualization highly depends on lighting and inspection condition and hence affects the performance the visual inspection system.

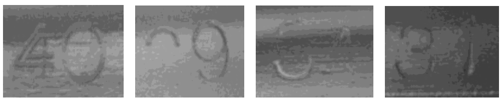


Fig. 1 Example of poor quality images

As the most images in FA environment including examples of Fig. 1 present poor quality visualization, conventional methods such as region segmentation, boundary tracing, or binarization could not adequate to be applied for the segmentation of the ID marks under uncontrolled and dynamic lighting condition.

2.1 Snakes algorithm

We introduce Snakes algorithm to solve the ID character segmentation problem in bad visualization images given from FA processes. The snake algorithm is based on the concept of active contours, which can be described as energy minimizing splines [9]. The concept of active contour is used very broadly in several previous papers and the related works [7-10]. It is an actively responding curve to the image features. Kass [9] has proposed a model called *Snakes* (i.e., active contour models) as an active spline reacting with image features. The contour is initially placed near an edge under consideration, and then image forces draw the contour to the edge in the image.

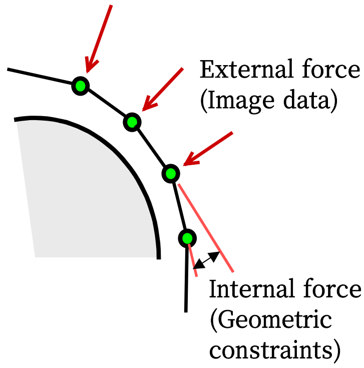


Fig. 2 Snakes algorithm: Advantage of Snakes algorithm could provide a *methodology* to impose geometric constraints while actively interacts to image data.

As the algorithm iterates, the energy terms can be adjusted to obtain a local minimum. That is, basic snake model is a controlled continuity spline under the influence of image forces. The internal spline forces serve to impose a piecewise smoothness constraint. The image forces push the snake toward salient image features. See the interaction between image data and active contour in Fig. 2. The active contour is represented by a vector, $v(s) = (x(s), y(s))$ having arc length s as parameter. Energy functional for the contour is defined by:

$$E_{\text{snake}} = \int_0^1 E_{\text{internal}}(v(s)) + E_{\text{external}}(v(s)) ds \quad (1)$$

where E_{internal} represents the internal energy of the contour due to bending or discontinuities, E_{external} is the image forces. The image forces can be due to various events, e.g., lines, edges, and terminations. The internal spline energy is written:

$$E_{\text{internal}} = \alpha(s)\left|v_s(s)\right|^2 + \beta(s)\left|v_{ss}(s)\right|^2. \quad (2)$$

The first-order continuity term has larger values where there is a gap in the curve, and the second-order curvature term will be large where the curve is bending rapidly. The value of α and β at a point determines the extent to which the contour is allowed to stretch or bend at that point. If α is 0 at a point, a discontinuity can occur, while if β is 0, a corner can develop. The minimum energy contour is determined using techniques of variational calculus [9] or a neighbor region search of the snake control points [7]. Advantage of Snakes algorithm could provide a methodology to impose geometric constraints while actively interacts to image data. This paper uses this idea of the Snakes algorithm to segment object ID characters in images of automation system.

2.2 Multiple templates

Suppose that it is impossible to extract the character regions from background of the inspection image if we use conventional binarization technique. In this section, we suggest a method to introduce multiple templates to find the character regions.

We form model templates from all characters included in the inspection images. Because all characters in input image are included in the template category, each pattern in the image corresponds to at least one character in this category. Searching the character area with these templates is to segment position of characters. That is, it is possible to search character area and recognize the character using template matching. However, in the case of poor quality images, this matching by single character template is also difficult and not reliable. Matching failure at preprocessing stage leads to recognition failure at post-processing of OCR algorithm.

In order to solve this problem, we propose multiple templates, which is composed of N multiple templates. In target object of automation process, ID marks are usually not single character and a few characters are successively written on object surface to be inspected. Multiple templates present the model that may include several characters instead of one template in a template model. Multiple templates increase the possibility of matching because correlation value could be increased N times than that of single template.

Fig. 3 shows the multiple template models. In designing multiple templates, there are some restrictions as follows.

(1) The size of each template must be same, if else, the size should be normalized to one size.

(2) No rotation and scale change in the character in input image. We only search the translation position the characters lie on.

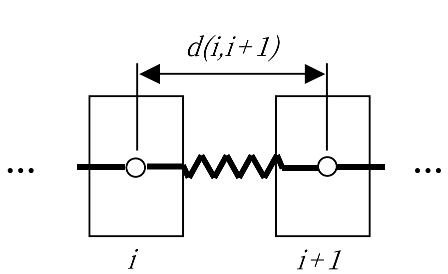


Fig. 3 Schematic of multiple templates model

Because multiple templates have to be successively connected, the *height* of each model template must be same for all model templates. In order to satisfy such condition, we normalized the size of template and treated matching with the pattern normalized from MBR (minimum boundary rectangle) of each template model.

Assume that object ID marks consist of N characters in inspection image. Hence, we should prepare the multiple templates with successive N characters. The number of total template model is M. Serial chain of multiple templates is configured for NGC matching using the prepared set of M model templates. The number of serial chain of multiple templates is same as the number of the characters in target image. Fig. 3 shows only two characters among whole serial chain. The M resulting values of NGC matching at *i*-th position are generated at neighboring locations of *i*-th position. The M resulting values of NGC matching at (*i+1*)-th position are also generated at neighboring locations of (*i+1*)-th position. Therefore, the number of combination of distance from matching positions generated by two successive templates is M^2. Because the numbers of serial chain are N, all possible path is M^{N-1} and we can define an optimal path search problem.

2.3 Modeling of ATM

The Snake paradigm models a deformable contour as possessing internal energy in order to impart smoothness to the contour. When this contour is located on an external energy field, the contour seeks a local minimum of the energy field by moving and changing shape. The ATM is a modified version of the conventional dynamic programming method [7] for Snakes algorithm.

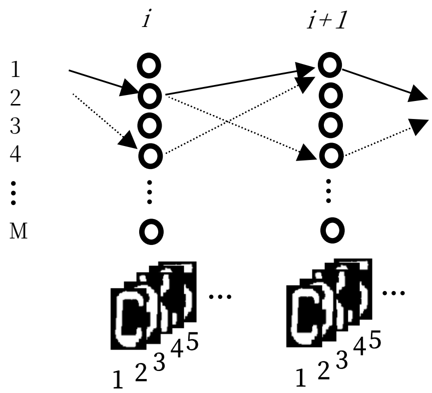


Fig. 4. Path search for character segmentation from dynamic programming

Fig.4 shows a concept diagram of path search using dynamic programming to segment character regions in poor quality images. First, assume that successive chain of characters is continuously positioned in any horizontal line in inspection image. The distance between two neighboring characters is not uniform and changeable. Then, full chain of templates try to find position of the N characters by overlapped to the horizontal line of the inspection image. Each node in *i*-th column of Fig. 4 presents optimally matched position at *i*-th stage of the N characters chain of templates. In each stage, there exist M node points because character category consists of M characters. The horizontal distance between two successive characters is changeable according to selection of any two linking nodes as the arrows of Fig. 4 present.

We try to find an optimal configuration increasing NGC coefficients while the distance between two neighboring templates maintains a predefined value $\bar{d}$. The value $\bar{d}$ is mean distance between two successive characters calculated from several object ID marks in inspection images. This term as the geometric constraint corresponds to internal energy of Snakes algorithm and enforces pulling or compressing spring force when there is any difference from the mean distance. The horizontal distance for any two nodes between *i*-th and *i+1*-th stage defines an internal energy of Snakes model as follows

$$E^{i}_{\text{internal}} = \frac{1}{2}\alpha \cdot (d(v_i, v_{i-1}) - \bar{d})^2 . \tag{3}$$

The external energy of eq. (4) presents the similarity ratio from the template matching by NGC algorithm. This energy describes the degree of pulling strength of image data for each template.

$$E^{i}_{\text{external}} = \frac{1}{2}\beta \cdot Corr(v_{i-1}) \tag{4}$$

$$E_{\text{ATM}} = \sum_{i=1}^{N} (E^{i}_{\text{internal}} + E^{i}_{\text{external}}) \cdot \tag{5}$$

Therefore, the ATM energy is defined as eq. (5) and minimized by the following recursive dynamic programming algorithm:

$$S(n,m) = \min_{k} \left\{ S(n-1,k) + E_{\text{ATM}}(v_{n,m}, v_{n-1,k}) \right\} \tag{6}$$

$$B(n,m) = k^{\min} . \tag{7}$$

Where $S(n,m)$ represents the accumulated minimal energy level and the back pointer $B(n,m)$ holds the index $k(k=1,...,M)$ giving minimum accumulation in each m step. After all stages have been processed, an optimal path is obtained by tracing back the pointers, beginning with the candidate that has a minimal $S(N,m)$ value. The time cost of the algorithm is a lower order $O(N-1 \cdot M^2)$, when compared to the complexity $O(N-1 \cdot M^3)$ of the conventional Snakes algorithm using DP search technique. For the more detailed discussion of the DP algorithm and its applications, refer to Geiger [10] and references therein.

3. Experiments

In order to verify the usefulness of the proposed segmentation algorithm, we performed several experiments with poor quality images such as character images acquired from the surface of glass panel marked by laser unit and IC wafers of semiconductor process.

In case of frontal laser marks on the glass panel, it is engraved by melting the glass surface with laser optical unit. The rough area written by laser is located at a side of the glass panel and includes characters to be identified. Since the surface is rough by laser melting, the character area could provide bright visualization by diffuse reflection effects. Also the character area is located on the surface of the transparent glass, the visualization is poor as the light permeates. In Fig. 5(a), there is an example of laser mark images engraved on CRT glass panel. It is not easy to obtain clear visualization of the character area because of transparent property of the glass. Fig. 5(b) shows an IC wafer image obtained from semiconductor process. Wafers have the characteristics that the surface is reflective and the patterns on the background are complex and very noisy. When the image quality is sensitive to the variation of inspection environment and lighting condition, the performance in conventional systems is seriously degraded.

We need template images to implement the proposed ATM algorithm. The examples of the templates are shown in Fig. 6 and the models normalized to size from original templates are used to find the frontal laser marks on the glass panel. The all templates normalized to size have same height and different width.

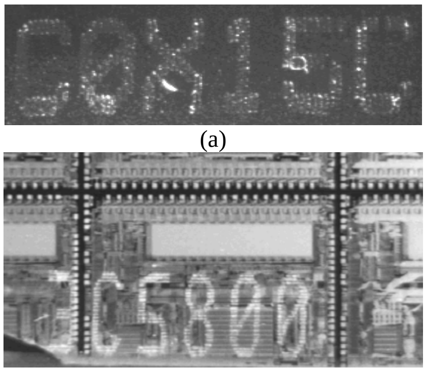


Fig. 5 Examples of poor quality images. (a) Frontal laser marks on CRT glass panel; (b) IC wafer image from semiconductor process.

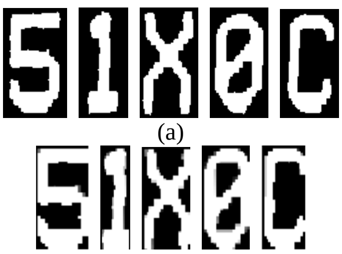


Fig. 6 Template images for analysis of frontal laser marks on CRT glass panel. (a) ID mark templates; (b)

Size normalization of the original templates

Fig. 7 shows the experimental result to divide the character regions with the single model template. In case of using single template, the segmentation of unknown character is not reliable and fails in many cases because of loss of character properties from poor visualization and noises in the inspection image. In other words, we cannot match and segment a specific character by template matching if we use one template indicating a character. For example, the template indicating the character “C” always matches and segments the mark “C” of last location among six ID marks in the input image, as shown in Fig. 7. Hence, we cannot separate the first character mark “C” in the image. The template “0” falsely matches to the character “5” in the input image and we cannot segment ID character “0” in the image. Also, we previously don’t know what characters exist in current inspection image and thus, all templates in the category of reference patterns should be tried to match the ID marks of the input image and this makes inevitable and frequent false matches.

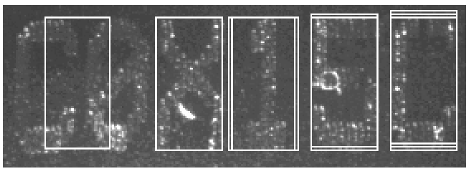
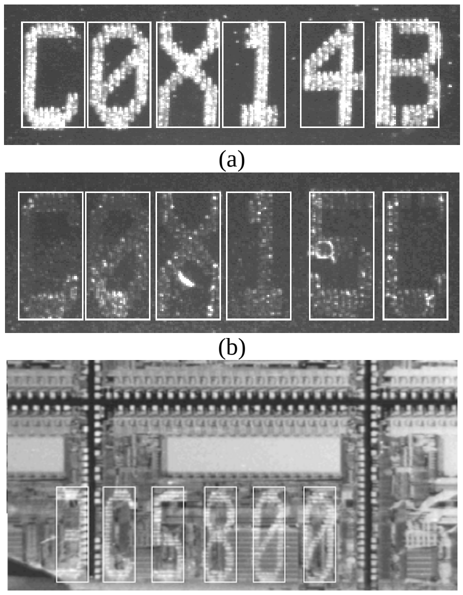


Fig. 7 Character segmentation by single template model

Fig. 8 shows the results of the character ID marks segmentation when we apply the proposed ATM method for a few images. Since these poor quality images have incomplete visualization, it is difficult to perform segmentation of the interesting character area with conventional methods. With a few additional examples, we proved the proposed methods well split unknown characters under bad visualization.
Because the time complexity of dynamic programming is proportional to the number of the model template in reference pattern category, the computational cost of ATM increases with the number of ID marks to be used. In the usual cases, template category of ID marks in FA processes is not large. In the experiment of Fig. 8(a) and (b), we use 10 model templates as the number of total reference pattern. We set the length of chain of ATM to 6-templates because the number of total ID marks in inspection image is six. Segmentation speed of the ATM requires about 1 sec in Pentium IV-2Ghz. Fig. 8 is another example from IC wafer manufacturing process and we have to prepare other reference patterns as model templates.



(a) (b) (c)

Fig. 8 Segmentation results by ATM. (a) Good visualization image of the CRT glass panel; (b) Poor quality image of the CRT image; (c) Wafer image.

Segmentation result of ATM is similar to Fig. 8(a) and (b). Because search region in the image is broader than CRT panel image, computational cost of ATM is higher than that of CRT image. To implement the practical segmentation algorithm to be applied in FA system, we should reduce the computational cost and any sensing and triggering techniques could restrict the search region of the input image.
Once we could segment character regions, then its possible to apply the character recognition algorithm such as artificial neural network or other graph search.

5. Conclusions

In this paper, we proposed an algorithm to solve the problem of the object ID marks segmentation for poor quality images of FA processes. Main contribution of this paper is a modeling of the functional modified from conventional Snakes algorithm to solve the character segmentation problem. The key idea of the proposed methods is based on the assumption that under poor quality images, each single ID mark does not sufficiently denote features of the character area, but if the features of the character area are shown iteratively and continuously in any horizontal line of the inspection image, the areas have high possibility to be the character region that includes several characters. Therefore, the multiple templates are introduced and applied to discriminate character regions in the images including object ID marks. We proposed the ATM algorithm as the elastic multiple templates model that includes the spring between two neighboring templates. Each template of the multiple templates interacts to image data through the NGC-based pattern matching while the distance between two neighboring templates maintains a predefined mean distance. We define an optimization problem to solve the ATM. Dynamic programming as a search tool is introduced to reduce computational cost in optimization of the defined functional. ATM algorithm successfully finds and segments the object ID marks in several bad visualization images obtained from conventional FA processes.

References

[1] R. Haralick and L. Shapiro, "Survey: Image segmentation technique," CVGIP, vol. 29, pp 100-132, Jan. 1985.

[2] S. Horowits and T. Pavlidis, "Picture segmentation by a tree traversal algorithm," J. CM, vol 23, pp. 368-388, Apr. 1976.

[3] S. M. Lee, "Low rate video coding using 3-D segmentation with two change detection masks", ISO/IEC/JTC1/SC29/WG11 MPEG93/941, Nov, 1993.

[4] C. K. Chow and T. Kaneko, Boundary detection of radiographic images by a thresholding method, in Frontiers of Pattern Recognition (S. Watanabe, Ed.), pp. 61-82, Academic Press, New York, 1972.

[5] A. Rosenfeld and A.C.Kak, "Digital picture processing," Academic Press, New York, 1976.

[6] S. Manickam, S.D.Roth, T. Bushman, "Intelligent and Optimal Normalized Correlation for High-Speed Pattern Matching, Datacube Technical Paper," Datacube Incorpolation, 2000.

[7] Amini, A., Weymouth, T.E., Jain, R.C., Using dynamic programming for solving variational problems in vision, IEEE Trans. Pattern Analysis and Machine Intelligence 12(9), 1991.

[8] D.J.Kang, A fast and stable algorithm for medical images, Pattern Recognition Letters 20, pp.507-512, 1999.

[9] Kass, M., Witkin, A., Terzopoulos, D., Snakes: Active Contour Models, Int. J. of Computer Vision 1, 321-331, 1988.

[10] Giger, D., Costa, L.A., Vlontzos, J., Dynamic Programming for detecting, tracking, and matching deformable contours, IEEE Trans. on Pattern Analysis on Machine Intelligence 17(3), pp.294-302, 1995.

[11] G.. Nagy, J.Kanai, M.Krishnamoorty, M.Thomas, and M.Viswanathan, Two complementary techniques for digitized document analysis, Proceedings of the ACM conference on Document Processing Systems, Santafe, New Mexico, pp.169-176, 1988.

[12] K. Aas, Verification of Batch Numbers on Plastic Vials, Proceedings of Scandinavian Conference on Image Analysis (SCIA'2001), O-Th4B, 2001.