QUALITY INSPECTION OF ENGRAVED IMAGE USING BASED MATCHING APPROACH

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(4th International Conference on Mechatronics (ICOM 2011),
17-19 May 2011, Legend Hotel, Kuala Lumpur)

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Quality Inspection of Engraved Image Using Shape-Based Matching Approach

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***bstract*—The role of machine vision system as a vital component r quality control mainly in manufacturing process cannot be enied. The system is developed to overcome the discrepancy om human vision and illumination changes. This paper roposes shape-based vision algorithm, a hierarchical template-atching approach that implemented in flexible manufacturing ystem to verify the quality of engraved image. Color and gray ale charged couple device (CCD) cameras are used to acquire igraved image for different kind of environment. The engraved nage is preprocessed using image processing technique. Region interest (ROI) is then selected and digitized into gray level to ctract the contour of the object using segmentation technique. he extracted contour is used as template for object recognition uring matching process. Several objects are engraved on the crylic souvenir bases with different color background to test the gorithm. This experiment result shows that the algorithm orks better with detection rate of 100% and matching accuracy more than 98%. The approach can be applied in packaging, harmacy, education, medical or any other areas which apply iape in their application.**

Keywords-engraved image; shape-based matching; gmentatio; flexible manufacturing system

I. INTRODUCTION

Flexible manufacturing system (FMS) is an advanced ianufacturing technology system which is widely applied in idustrial automation. This system has the capabilities on roducing new diversity of products for the market consuming a short time and managing the flexibility in product design. ne of supporting element in FMS is a machine vision ispection system and it becomes a crucial part in performing sk on object verification and decision making process. In fact, the vision system invention is evolving rapidly along with the growing technology and image processing software development.

For over decades, substantial investments from huge companies on vision system researches have been conducted intensively. Therefore, various approaches are introduced and implemented in manufacturing system with the same goal to improve the quality and productivity.

Human inspection is a traditional method that can cause misjudgments and run a little bit slower. The inspector usually verifies the object at the final stage of manufacturing process. It will create losses since the defect product has been through the entire processes. This problem will be an obstruction for the competitive companies to fulfill the market demand. Hence, the vision system development must be flexible enough to inspect the various types of features, high speed, efficient in recognizing the objects presence, verify the objects and inspect the object's quality [1].

In this study, shape-based vision algorithm [2]-[3] is applied to qualify the object quality before go for the next process. The algorithm is tested on FMS which operates in computer integrated manufacturing (CIM) environment using a model located in the Industrial Automation and Robotics research laboratory of Universiti Teknikal Malaysia Melaka. The model is customized to produce a take-away souvenir with any form of engraved image on the various colors base. Now, the model is running without the inspection system and will create losses because the defect product still has been through the entire process.

This paper proposes a vision algorithm base on shape analysis by means of template matching approach in verifying

This project was supported by Universiti Teknikal Malaysia Melaka and inistry of Higher Education Malaysia.

78-1-61284-437-4/11/$26.00 ©2011 IEEE

ıe quality of object interested on engraved image. This paper ; organized as follow; the related background of the research ; explained in Section II, the system principle and ıethodology is described in Section III and the experiment ɛsult and analysis are detailed in Section IV.

II. RELATED WORK

Template matching based on shape approach have been ɔplied in machine vision system mainly for manufacturing ıdustries. Color, texture, and spatial relationship ıaracteristics also have been investigated and implemented as ɛference to perform the specific tasks [4]. Template matching ɔproach is applied in checking the quality of printed circuit ɔard [5]. The researchers applied normalized cross ɔrrelation (NCC) in computing the matching score of the ɛference object for template and candidate comparison. Three ıethods to register template which is direct representation ıatching (DRM), principal axes matching (PAM) and circular rofile matching (CPM) are studied and compared to identify ıe imprinted tablet quality [6].

C.T. Huang et al [7] proposed color characteristics to ualify the product quality on LabVIEW platform and IMAQ ision tool. They inspected the product quality by red, green ıd blue values obtained from the region selected. The value ɔllected complies with the standard value to distinct good and ɛfect products. Color feature is employed to extract ɔmponent body and identified an electrodes position in ıspecting the quality of surface mounted components [8]. ɛeypad quality for cellular phone had been proposed by Du heol Gang et al using principal component analysis (PCA) ɔr registering the reference image in order to detect font error, ɛratches, and color difference [9].

Shape characteristic is applied on the inspection of surgical ıstruments such as scissors, forceps and clamp [10]. The ʼidth dimension of those instruments are measured and ɔmpared to the standard specification given by the surgeons. ɛancheng Jia inspected medical syringes assembly on two ımple images; needle end vision and thumb end vision [11]. ʼhe tolerances for measurement have been set up based on ıanufacturer's standardization using pattern matching ıethod. Such approaches also have been implemented and eveloped to inspect the quality of bottling system [12][13], ıd size measurement [14][15].

Texture analysis is studied by Jiaoyan Ai and Xuefeng Zhu ɔ detect pit and spot-like defect on the ceramic glass surface 16]. They measured the distance in the sub-image histogram ɔ detect the pit and applied Markov random field approach for ɔot-like detection in their research. Texture recognition also ad been studied to identify several defects on magnetic disk ırface such as head ding, contamination and sputter using ınking order co-occurrence spectrum [17].

III. SHAPE-BASED VISION ALGORITHM

This research is an extended concept done by W.T. Lim et al in the study on the pattern recognition using shape template-matching algorithm to control the subsequent process [2]. The algorithm is designed using image processing tool provided by MVTec Halcon machine vision software to detect the object presence and measure the matching accuracy. This approach consists of two phases which is training phase and recognition phase as depicted in Fig. 1.

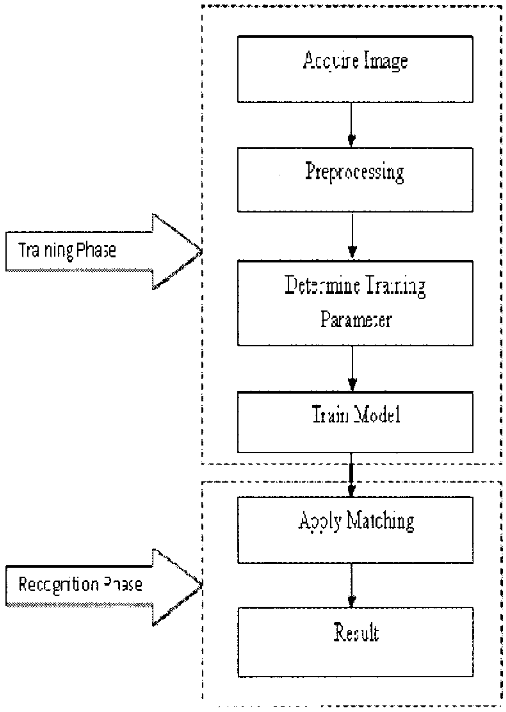


Figure 1. Shape based matching algorithm.

A. Training Phase

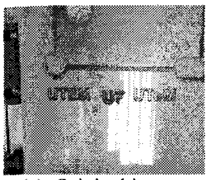
1) Image Acquisition: The image is captured by CCD color and monochrome digital camera for different kind of environment under the ambient light. Camera focus and distance between camera and object are adjusted for better and sharper image. To enhance the visual quality of the image under inspection, black background has been added at the back side of the object to obtain the high contrast image.

2) Image Preprocessing: In this step, the acquired image is processed to eliminate noises inside the image simultaneously enhancing the result of the output. The methods used in this stage are listed as below :

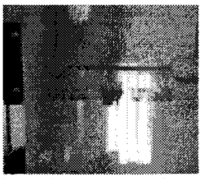
a) Color Filtering: color filtering is applied to decompose the color image which consists of red, green, and blue component into gray scale image by

$$f(x,y) = 0.299 * r(x,y) + 0.587 * g(x,y) + 0.114 * b(x,y) \quad (1)$$

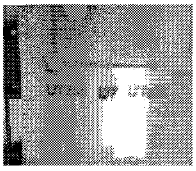
where *f(x,y)* is the gray value for x,y coordinate respectively, *r(x,y)* is the Red value for x,y coordinate respectively, *g(x,y)* is the Green value for x,y coordinate respectively, and *b(x,y)* is he Blue value for x,y coordinate respectively. The original olor image used as in Fig. 2(a) and its components images are hown in Fig. 2(b), 2(c) and 2(d).



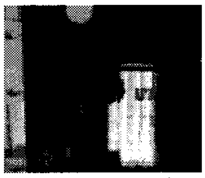
(a) Original image.



(b) Red component image.



(c) Green component image.



(d) Blue component image.

Figure 2. Color image and its component.

b) Smoothing Filter: mean or averaging filter is applied) retain the image's useful features. The value of each pixel is eplaced by the average values in the local neighborhood ased on equation (2). This filter helps in removing the grain oise from image and speed up the process compared to the lassical median filter.

$$\hat{f}(x,y)=\frac{1}{mn}\sum_{(s,t)\in S_{xy}} g(s,t) \qquad (2)$$

3) Image Enhancement: Gray level image is defined by

$$g_{res}=((g_{orig}-g_{mean})*Factor)+g_{orig} \qquad (3)$$

) enhance the quality contrast of the image. g_{res} is the esulting gray values, g_{orig} is the original gray value, g_{mean} ; the obtained gray values from low pass filter and *Factor* is ie intensity of contrast emphasis.

4) Region of Interest (ROI) Creation: ROI selection can be single or multiple objects as depicted in Fig. 3(a) and 3(b). 'his is manually done by the user to allow the inspection to be one on the desired or critical area. The ROI creation ensures iat only specific part of the image will be used for the next age. ROI has several advantages such as to speed up the rocess because it contains fewer pixels, focuses only on the specific area and can be used as template.

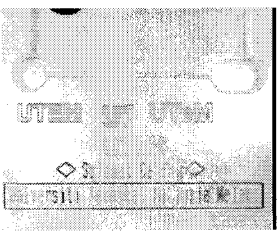


Figure 3(a). Single ROI created.

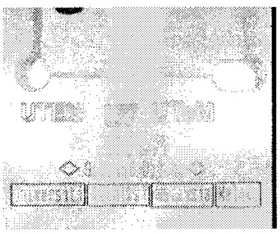


Figure 3(b). Multiple ROIs created.

5) Image Segmentation: The ROI(s) on decomposed image is segmented by means of threshold the image to extract the shape of the object. Fig. 4 shows the shape obtained, called template is representing the model and appears during the matching process. Since the object comes on variant color backgrounds, the image contrast is affected during the matching process.

Figure 4. Shape image.

Threshold method is applied to overcome the color contrast and invariant illumination changes. The gray value ranging from $g_{\min}=0$ to $g_{\max}=2^b-1$ refer to the pixels that belong to the foreground object is adjusted to get the dominant object for inspection. The gray value f which is selected pixels from the input image must fulfill the following condition

$$g_{\min} \leq f_{r,c} \leq g_{\max} \qquad (4)$$

6) Train model: One or more models can be created respectively to the ROI selection. The ROI image together with control parameters such as number of pyramid levels and contrast value are very important and affected in recognition phase. Image pyramid concept really helps by speeding up the matching process even if the search images have contrast variation. Image pyramid consists of the original, full-sized image and a set of down-sampled images as shown in Fig. 5. The number of the pyramids level is set as much as possible so that the model is still recognizable and contains a sufficient number of points on the highest pyramid level.

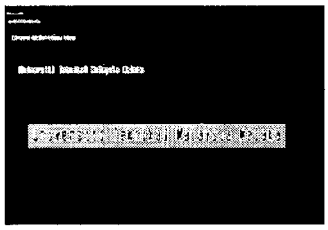


Figure 5. Pyramid image.

B. Recognition Phase

1) Apply Matching: The searching and matching process are the crucial part to find and localize object on search image due to the contrast variation. This process is done by placing he template on a search image. Shape model presence on earch image is detected by comparing the intensity values in he template with the corresponding values in search image. The similarity between the template and the candidate on a earch image are compared and measured as in (5). There are everal techniques to perform template matching; sum of bsolute differences (SAD), sum of square difference (SSD), nd NCC. NCC performs efficiently in terms of speed and ccuracy compared to the others. An equation of NCC is

$$NCC(x,y)=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(S_{XY}(i,j)-\bar{S}_{XY}\right)\left(T(i,j)-\bar{T}\right)}{\left\{\sum_{i=1}^{M}\sum_{j=1}^{N}\left(S_{XY}(i,j)-\bar{S}_{XY}\right)^2\sum_{i=1}^{M}\sum_{j=1}^{N}\left(T(i,j)-\bar{T}\right)^2\right\}^{1/2}} \quad (5)$$

here $\bar{S}_{XY}$ is the average value of candidate object on search nage, S_{XY} and, $\bar{T}$ is the average value of the mask and eferred as template image, T. The NCC has value in the inge of -1 and 1 where 1 indicates the perfect match and -1 or the reverse polarity. The maximum correlation occurs hen the normalized template and the corresponding ormalized object on a search image are identified and idicates as best possible matching score. Matching score is a erm used to express the similarity which measuring how any model points could be matched to points in the search nage.

2) *Visualize Results:* In this stage, the model contours at overlap at the found position of the search image are isplayed with the best matching possibility in percentage alues and execution time for detecting the object.

IV. RESULTS AND DISCUSSION

The engraver machine EGX-300 which has the capability engrave any form of image that has been created by user is et up to test the algorithm. Acrylics material bases with ifferent color background; red, blue, yellow, green, pink, hite, and purple are used for various contrasts and engraved ith similar pattern object. The images are captured by digital olor camera with resolution 640x480 and monochrome amera for gray scale image with resolution 720x480. MVTec Ialcon vision software is used to process and analyze the nage.

The experiment is initially done by means of obtaining the est background color that will be used as an object template. ig. 6(a) depicts that values of matching percentage on green ackground is closely near compared to other colors.

Two prerequisite parameters are identified to enhance the rocess; minimum score that shows high comparability, ained shape invisible in the image and greediness that shows e rate of searching process. Greediness within the range alue from 0 is safe but slow and 1 much faster but object may e missed. Fig. 6(b) and 6(c) shows the optimum value of reediness is 0.7 and minimum score within the range 0.65 to 0.8. The green color base and both of the values are employed in the following step to determine matching accuracy in color and grayscale vision.

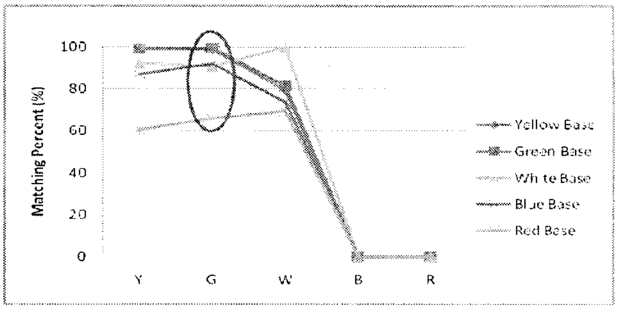


Figure 6(a). Data for object background determination.

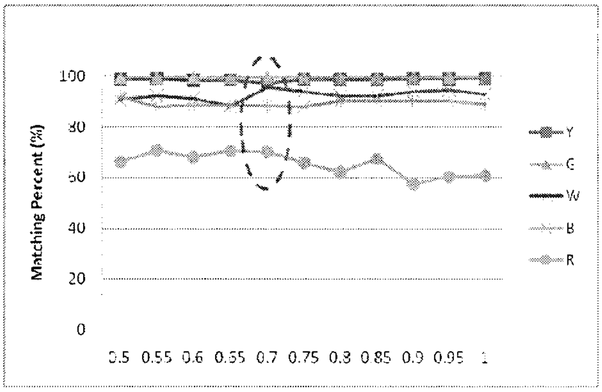


Figure 6(b). Data collected for variant Greediness.

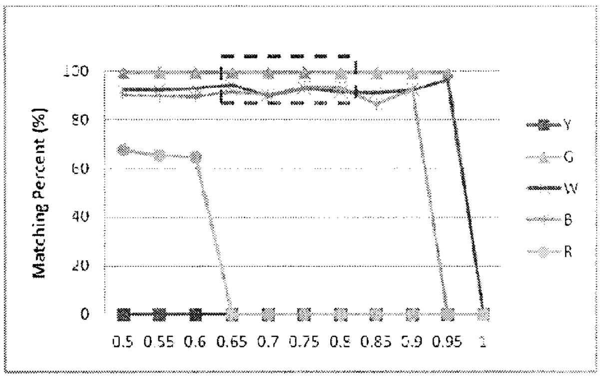
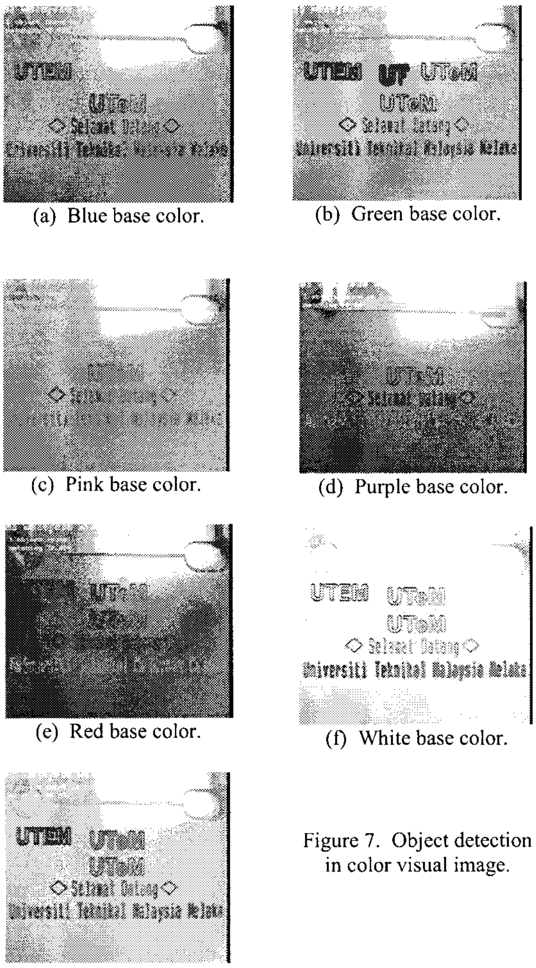


Figure 6(c). Data collected for variant MinScore.

A. *Color Vision Image*

Fig. 7(a) - (g) shows the template is coincidence successfully on the candidate object respectively and yields recognition rate more than 95 percent except red background with time execution less than 0.1 second as depicted in Table I. Candidate object on red can be detected by proper lighting set up to enhance the object and background contrast. Template matching based on shape performs very well in color vision by transforming the color image into their RGB components during training and recognition process.



(a) Blue base color. (b) Green base color.

(c) Pink base color. (d) Purple base color.

(e) Red base color. (f) White base color.

(g) Yellow base color.

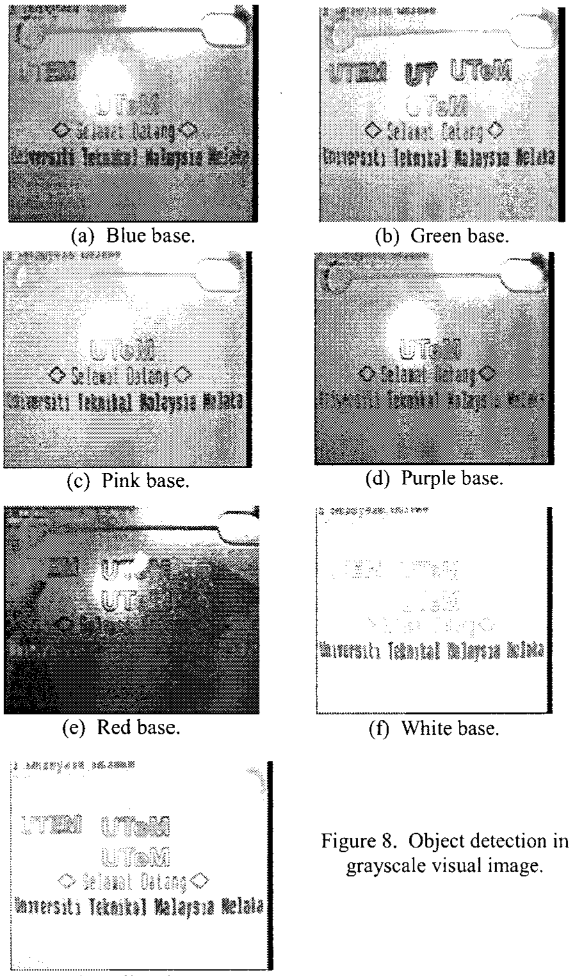
Figure 7. Object detection in color visual image.

TABLE I. PATTERN MATCHING SCORE IN COLOR VISION

Template	Digital Color Camera		
	Search Object's Background	***Matching (%)***	***Time (s)***
Object on Green Background	Blue	98.89	0.01
	Green	99.47	
	Pink	98.77	
	Purple	98.06	
	Red	72.61	
	White	99.33	
	Yellow	98.57	

B. *Grayscale Vision Image*

High matching percentages as shown in Table II indicates hat proposed method is detected and inspected the object ccurately. However the score of the object on red background s the lowest due to the minor contrast between the object. urthermore the object surface contains lots of noise resulted from the coarse texture. Fig. 8(a) – 8(g) show the overlapping template on candidate object in grayscale visual images.



(a) Blue base. (b) Green base.

(c) Pink base. (d) Purple base.

(e) Red base. (f) White base.

(g) Yellow base.

Figure 8. Object detection in grayscale visual image.

TABLE II. PATTERN MATCHING SCORE IN GRAYSCALE VISION

Template	Digital Monochrome Camera		
	Search Object's Background	***Matching (%)***	***Time (s)***
Object on Green Background	Blue	97.84	0.01
	Green	99.84	
	Pink	96.64	
	Purple	96.51	
	Red	77.64	
	White	96.07	
	Yellow	97.24	

V. CONCLUSION

In this study, shape-based matching vision algorithm is proposed to inspect the quality of engraved image on various color background of acrylic souvenir material in both color and grayscale vision. The result shows that colors are affected in recognition and searching process of template matching. By means of converting the color image into their color components, object detection task is performed in high accuracy and efficiently. The best filtering, segmentation, and ROI selection in template creation are very useful techniques to enhance the image contrast in matching process. This approach evidently shows that shape-based matching is robust on the contrast variation, effective on rotation and translation, faster in detecting and verifying the object quality, and high flexibility to satisfy the FMS characteristics'.

ACKNOWLEDGMENT

The authors would like to thank Ministry of Higher Education and Universiti Teknikal Malaysia Melaka for financial support on this project.

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