Firing Pin Impression Segmentation using Canny Edge Detection Operator and Hough Transform

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***Abstract*—Firearms identification based on the forensic ballistics specimen is crucial in solving criminal case in a short time. Currently, the firearms examiners perform authentication by visual observation. Due to observation of large evidence database, the experts normally take a long time to identify the firearms. As a result, computerized firearms identification should be implemented in order to perform the identification faster. The computerized identification involves image preprocessing, segmentation, feature extraction and classification. Therefore, in order to reduce computational time, the segmentation has to be performed automatically. The main objective of this study is to perform the segmentation of firing pin impression by using Canny edge detection operator improvised with Hough transform. The performance of segmentation in detecting the central image of firing pin impression has achieved 93% segmentation accuracy.**

***Index Terms*—Canny Edge Detection; Hough Transform; Firing Pin Impression; Segmentation.**

I. Introduction

Automatic ballistics identification system such as IBIS was developed to help investigators to trace the relevant crimes. It usually takes a long time because of the huge number of firearm evidence in database. Further, the number of firearms to be matched is usually too large. In a September 2004 report, the Maryland State Police (Forensic Sciences Division) addressed the continuing problems of the MD-IBIS system, including the inability of the MD- IBIS to expedite crime investigations. The digital images are stored in a database and analyzed using a software program. The database used to store the images is very large. Figure 1 describes the process for entering the ballistic data into the IBIS system [1].

In order to identify the firearm efficiently, an automatic identification system is indeed much needed to quickly narrow down the possible number of required match. Due to this problem, the features values to represent images are more effective to be stored in database that require small database instead of images. Researchers have found that geometric moment up to the sixth order in the form of numerical features has been used for the classification of the firing pin impression images into the respective classes using discriminant analysis as classifier with successful rate 96. 7%. However, they have performed only manual image segmentation which is one of the most important steps leading to the pattern recognition [2]. The segmentation process should be run automatically in order to reduce processing time. Image segmentation is a promising and challenging field which is applied in the area of medical imaging, satellite images, biometric identification and pattern recognition [3]. Therefore, in this paper, the technique known as Canny edge detection improvised with Hough transform is applied to perform segmentation of firing pin impression image. In other words, it is used to separate the center image from the unwanted background information of whole image.

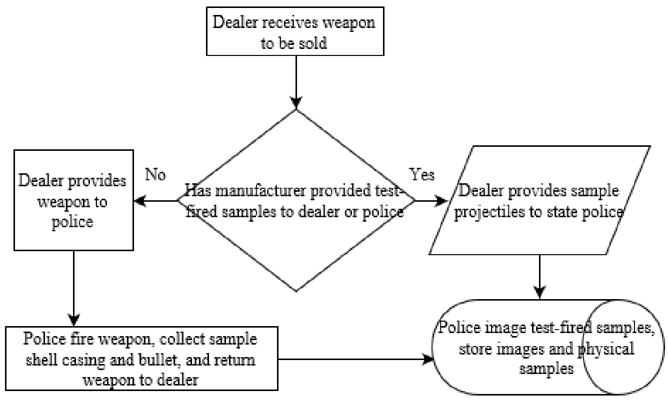


Figure 1: The process for entering the ballistic data into the IBIS system

Canny edge detection has been developed in 1986 by John Canny[4]. Canny edge detection operator is one of the most superior operators for edge detection. It is commonly used in image processing as it meets the general criteria's for edge detection[5]. Comparatives study of the popular edge detection algorithms (Roberts, Prewitt, Sobel, LoG and Canny) has been conducted and the result proves that the top two, Log and Canny operator have achieved the highest performance, which are 76.52%, Canny 75.79% respectively. Their most important advantages compared to other techniques are the simplicity of use and efficient run-time detection[6].

There is another comparative study proving that Canny edge operator is better than Sobel edge operator. Table 1 shows the comparison of the two techniques [7].

M. Rafati et al. have also found in their research that Canny edge detection operator with SRAD filter is better than Sobel, Prewitt, Robert and LoG edge detections operators with SRAD filter in terms of speckle suppression and details preservation in brachial arteries ultrasound images. Their result has been summarized as shown in Table 2, showing that the Canny operator has the best performance due to the lowest mean of mean square error, MSE and the highest values of peak signal to noise ratio, PSNR. [8].

Table 1
Comparative Study of Sobel and Canny Edge Detector

Technique	Sobel	Canny
Computational Complexity	Simple	Complex
Edge Detection	Coarse edges detected	Fine and coarse edges detected
Image pattern Detection	Blur image detected	Clear image detected
Input image complexity	Suitable for simple image with less edges	Suitable for almost all images even the complex one.

Table 2
Mean MSE of SRAD de-Noising filters and Different Edge Detection Operators in left Brachial Artery

SRAD Filters					
Technique	Canny	Sobel	Prewitt	Roberts	LoG
Mean MSE	0.0005	0.0009	0.00109	0.00108	0.0012
Mean PSNR	81.7820	78.3043	77.9029	78.0852	77.4316

The MSE and PSNR of the output image are defined as:

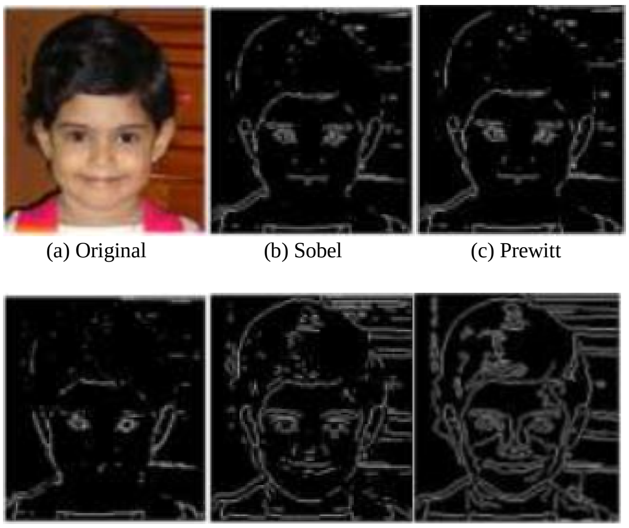
$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[X(i,j) - Y(i,j)]^2}{MN} \quad (1)$$

where $X(i,j)$ is the original image, $Y(i,j)$ is the next image in sequential images and MN is the size of the image.

$$PSNR = 20\log\left(\frac{L}{\sqrt{MSE}}\right) \quad (2)$$

where L is the maximum value and MSE is the mean square error[8].

In a further study, edge detection of all the five operators has been performed by P. Acharjya et al. Among the five edge detection operators, Canny operator yielded the best result as pictured by the Figure 2[9].



(a) Original (b) Sobel (c) Prewitt

(d) Robert (e) LoG (f) Canny

Figure 2: The edge detection by using five edge detection operators

All the findings mentioned before lead to the conclusion that Canny edge detection operator is the best for the purpose of edge detection. Therefore, in our study, Canny edge detection technique is chosen based on two characteristics. The first and the most important characteristic is low error rate. It is important that the segmentation is accurate since the purpose of the next studies is to extract feature in order to classify the pistol's firing pin impression. The accuracy is important in this case because it involves law. The second characteristic is that Canny operators are able to process complex images. This is very important because the image of cartridge case is quite complex.

The important part of the image to be segmented is actually circular in shape. Due to its circular shape, it is best to integrate Canny edge detection technique with Circular Hough Transform. This idea is triggered by the approach that have been implemented by J. Ni et al. [10] to count circular shaped overlapped objects using Circular Hough Transform.

Furthermore, there is a comparative study by Z. Zainal Abidin et al. showing that Hough transform technique perform better than Integro_Differential Operator for circle segmentation. The Integro-Differential Operator has performed the accuracy of segmentation by 22.06% of the images, while Hough Transform has successfully segmented 80.88% from the CASIA database of eye images[11].

As a result, the technique chosen is the integration of both Canny edge detection and Hough Transform prior to our segmentation.

II. CANNY EDGE DETECTION ALGORITHM

Canny operator is widely used in research related to image processing specifically in edge detection. It satisfies the general criteria for edge detection. Canny edge detector uses a multistage algorithm. The stages involved in Canny edge detection is shown in Table 3 [5]:

Table 3
Multistage involved in Canny edge detection algorithm

Stage	Function
1. Smoothing and blurring	To remove noise from the image
2. Finding Gradients	Abrupt change in the intensity in between two pixels produce gradient. Edges with maximum magnitudes of gradients would be marked.
3. Non-maximum suppression	The edge would be chosen among the marked edges by selecting local maxima.
4. Double thresholding	To determine the prospective edges
5. Hysteresis	To track the edges so that the all edges are connected.

III. CIRCLE HOUGH TRANSFORM

The circle Hough transform searches the optimum values of radius, r and the center of the circle, (x_c, y_c) following the mathematical Equation (3):

$$H(x_c, y_c, r) = \sum_{i=1}^{n} h(x_i, y_i, x_c, y_c, r) \quad (3)$$

where $h(x_i, y_i, x_c, y_c, r) = (x_i - x_c)^2 + (y_i - y_c)^2 - r^2$

for edge point (x_i, y_i), and $i = 1,2, \dots, n$.

IV. Implementation

A. Data Collection

The cartridge case image data were secondary to the ones compiled by N. Md Ghani et al. The data of radius and centre of the manual segmented images were also obtained from N. Md Ghani et al. [2]. The subjects in this research involved five pistols of Parabellum Vektor SPI 9 mm model. The crucial characteristic of the pistols chosen is the capability of producing similar firing pin impression images for the purpose of image recognition later on. The subjects were labelled as Pistol A, B, C, D and E. There were 150, 150, 150, 149 and 148 cartridge case images produced by Pistol A, B, C, D and E respectively. The cartridge case image was not affected by lighting problem since it was captured using efficient CONDOR System. Therefore, there was a total of 747 cartridge case images that have gone through the segmentation process automatically. The shape of the firing pin impression was a circular pin mark. This circular pin mark would be segmented from the original cartridge case image which is known as firing pin impression image.

B. Evaluation of Segmentation

The method proposed in this paper is implemented using MATLAB R2009b. Since we have 747 cartridge case images to be segmented

1. Firstly, the image was retrieved and the Canny edge detection was employed to generate an edge map. Edges were detected at the locations where neighborhood pixels had abrupt changes in their intensities.
2. Secondly, Circular Hough transform was applied in order to detect the circular contour. The Circular Hough transform extracted the parameter values of radius and center of the circle of the firing pin impression image. The range of radius of firing pin impression has been set manually, depending on the database of all images.
3. Thirdly, the detected contour of circular edge was drawn. The circular contour of firing pin impression from the respected groundtruth image was also drawn.
4. Lastly, the segmented image produced then would be compared with the manual segmented image as a ground truth segmented image. The accuracy of automatic segmentation of each automatic segmented image was calculated based on the number of pixels overlapped in both segmented images over the union of number of pixels of both segmented images. The performance of segmentation of each image in this study was measured based on the following rule.

$$\frac{n(R \cap S)}{n(R \cup S)} \times 100\%$$

where R and S represent pixels of reference image(ie, groundtruth) and segmented image respectively.

The work flow of the proposed approach is shown in Figure 3.

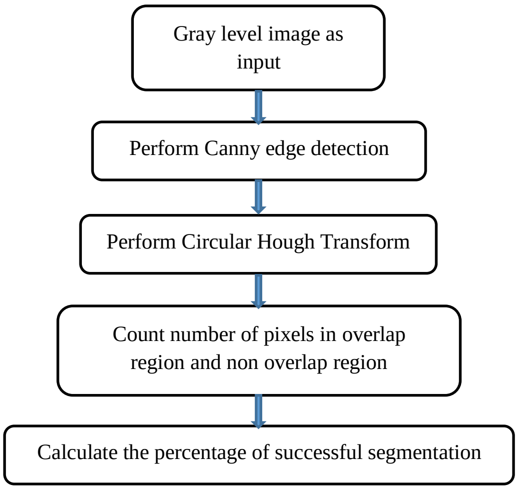


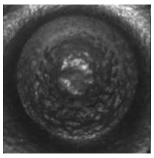
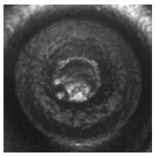
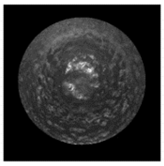
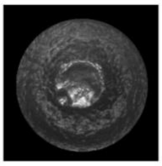
Figure 3: Flow diagram of segmentation implementation

The purpose of the subsequent segmentation was to extract the feature from segmented image for the purpose of firing pin impression classification. This would be conducted in our further research.

V. Results And Discussion

Table 4 shows the results of successfully segmented firing pin impression images by using the proposed technique.

Table 4
The segmentation of firing pin impression images

Image	A001FP3	B001FP3
Original Image (cartridge case image)		
Segmented Image (firing pin impression image)		

The evaluation of the proposed technique was measured based on the size and location of the circular region. In this experiment, we obtained the value of radius *r* and the centre of the circle (*x*,*y*) of the segmented image in order to describe the size and location of the circular region. From the value of the radius and centre, we plotted the respective segmented circle. After that, we plotted the groundtruth circle. The calculation of number of pixels of overlap region in between segmented and groundtruth image, number of pixels of segmented image and number of pixels of groundtruth image was implemented using Matlab. In order to evaluate the performance of segmentation, the region was measured using the technique of Jaccard Similarity Measure(JSM). The ratio obtained from JSM was then multiplied with 100% in order to get the performance in percentage. This is simplified in the form of equation below:

$$\frac{n(R \cap S)}{n(R \cup S)} \times 100\%$$

or

$$\frac{n(R \cap S)}{n(R) + n(S) - n(R \cap S)} \times 100\%$$

where R and S represent pixels of reference image(ie, groundtruth) and segmented image respectively.

The performance of several images of each image in percentage is shown by Table 5. The average performance of segmentation of 747 images is 93%. Since this is the first trial to segment the firing pin impression image automatically, 93% is considered as an acceptable segmentation accuracy.

Table 5
The performance of segmentation for a few images

Image	n(R∩S)	n(R)	n(S)	Performance (%)
A001FP3	68813	73542	68813	93.6
A002FP3	58107	58107	90792	64.0
A003FP3	63347	65144	63347	97.2
B001FP3	75410	76454	75477	98.5
B002FP3	78427	80425	78427	97.5
B003FP3	78427	80425	78427	97.5
C001FP3	73084	78427	73542	92.6
C002FP3	70686	73542	70686	96.1
C003FP3	81723	82448	82448	98.3
D001FP3	81967	84496	82448	96.5
D002FP3	80349	83469	80425	96.2
D003FP3	78098	80425	78427	96.7
E001FP3	68813	74506	68813	92.4
E002FP3	68813	72583	68813	94.8
E003FP3	68813	72583	68813	94.8

VI. CONCLUSION AND FURTHER WORK

The traditional canny edge detection operator has the capability of identifying very fine edges, while circular Hough transform is capable to identify circular shape. These two characteristics of these techniques will lead to a better performance of our experiment for segmentation of circular region. Based on the experimental results, we can conclude that Canny edge detection integrated with circular Hough transform has successfully segmented the circular image of firing pin impression with 93% accuracy. Since the later purpose of segmentation is for classification of firing pin impression, it is crucial to increase the performance close to 100%.

In order to improve the segmentation, we propose that morphological filters' operators such as erosion and dilation would be used prior to the Canny edge detection. In this way, the segmentation of firing pin impression image can be segmented into whole image, centre image and ring image automatically. Figure 4 is an example of the manually segmented image that has been done.

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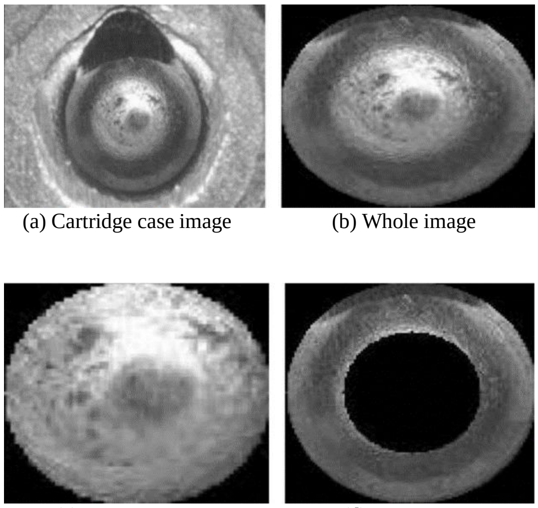

(a) Cartridge case image (b) Whole image

(c) Centre image (d) Ring image

Figure 4: Segmentation of firing pin impression into three parts manually (b), (c) and (d)

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