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A pilot study on image processing methods for segmentation of striations in fired bullets

Lipi B Mahanta[1*], Kangkana Bora[2], Rahul Kumar[3], Shauvik Purkayastha[3], and R Suresh[4]

[1]Central Computational and Numerical Studies, Institute of Advanced Study in Science and Technology, Guwahati, India
[2]Department of Electronics and Electrical Engineering, Indian Institute of Technology, Guwahati – 39, India
[3]Department of Computer Science and Engineering, Assam Engineering College, Guwahati - 781013, India
[4]Central Forensic Science Laboratory, Directorate of Forensic Science Services, Ministry of Home Affairs, Government of India, Guwahati, India

**Corresponding Author: lbmahanta@iasst.gov.in*

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Abstract— The rise in crimes and the use of firearms necessitate ballistic and forensic science laboratories worldwide to come up with quick and accurate solutions. The identification process of firearms is a complex yet very sensitive and vital step in evidence examination in the process of crime investigation. The use of modern techniques like image processing and pattern recognition can contribute to increase the accuracy as well as reduce the time in the process of identification. Manually, many features of a spent bullet of a firearm are investigated for this purpose, striations being an important one of them. The aim of the study is to automatically segment out the striations present in a fired bullet through image processing and segmentation techniques, which is a real challenge as these marks are very fine. For the study, images of two fired bullets of .22 in. caliber rimfire cartridge, fired from one and the same firearm (semi-automatic pistol) were considered for the preliminary study. Experimental results show that proposed techniques can be efficiently used for firearm identification through digitizing and analyzing the fired bullets specimens. The visual comparison reveals that the Fuzzy C Means technique gives the clearest segmented result of the striations. This could be of great use in the future as it is a time-saving process. This can be of great help in feature identification, vis-à-vis manual searching of the feature under a comparison microscope for identification of the firearm.

Keywords— Ballistic, Firearm identification, Striations, Segmentation

I. INTRODUCTION

The true identification of ballistics specimens from imaging systems are important applications of technology in a criminal investigation. Firearm identification is an intensive and time-consuming process that requires a physical interpretation of forensic ballistics evidence [1]. The necessity for a quick, robust and accurate firearm identification system by police and law enforcement agencies continues to rise mainly due to greater availability of weapons in the international market, bringing along with it a surge in crimes with these weapons.

The characteristic markings on each fired bullet are known as striations, the examination of which is very important because it contains a unique pattern for matching. When a firearm is discharged, the gun barrel leaves striations on the surface of the bullet and the gun's firing pin, breech face, chamber, extractor and ejector imprint the casing with distinct markings. These markings comprise a "bullet signature" and a "casing signature" that is considered unique to each firearm. The forensic examination of ballistics specimens relies on the detection, recognition and ultimate matching of markings on the surfaces of fired cartridges and projectiles made by the firearms evidence [2]. Traditional ballistics identification is a labor-intensive activity with several weeks of time being devoted to a single analysis and comparison. The need for a scientific basis for such an identification has been well discussed [3]. A simple technique applying a stereomicroscope, digital camera, and a computer system to compare two fired cartridge cases based upon their unique markings was presented by [4]. This technique could be further augmented with the use of modern methods of digital image processing systems, which not only have the potential to reduce this period for identification of several hours but it also ascertains the better visualization of the specimen for positive identification with great precision. More than thirty different features within these marks can be distinguished, which in combination produce a signature for identification of the firearm [5]. Hence it is clear that automation of identification of firearms using these distinguishing features is the need of the hour in the world of forensic ballistics and would play a vital role in legal evidence analysis where firearms are involved. The importance of digital image processing on different applications has been expounded in [6]. Segmentation process offers a means to extract a particular region of interest (RoI) inside an image for better analysis. Some segmentation techniques were reviewed by [7]. In the field of ballistics, some studies [8],[9],[10],[11],[12],[13],[14],[15] have been done to develop systems to integrate digital imaging, database and networking technologies to enhance the capabilities of the forensic firearm examiners. This motivates us to make a study to make a feasibility study to automate the process of segmentation of the RoI, viz. the striations, which is the foremost basis for successful feature extraction and classification. In this study we consider only the surface of the bullet to find out the striations using image processing techniques.

The rest of the paper is of the paper is organized as follows: Section II gives a brief review of the overview of the work and methods used in different steps. In section III, we presented the experimental results and in section IV we give the direction of our ongoing and future work. Finally, a conclusion is presented in section V.

II. RELATED WORKS

A table (**Table 1)** comprising of related works in this domain is given below:

Table 1. Literature review with comparison

Authors	Year	Feature studied	Method
Li [1]	2003	Cartridge case	image pre-processing based on Canny edge detection
Nigam et al. [2]	2014	Bullet striation marks	Corel Paint Shop Pro Photo X2
R. Suresh [4]	2017	Firing pin marks	Microsoft office (Windows 8 tools)
Geradts et al. [9]	2001	Breech face marks and firing pins	2D cross image matching function image matching for tracking (KLT-method) algorithm
Mazumdar et al. [11]	2002	Bullet cartridge headstamp	circular invariant class separator for segmentation and matching
Li [12]	2006	Markings on the cartridge case and projectile	Fast Fourier transform
Xie et al. [13]	2009	Class characteristics and individual characteristics	Surface topography techniques
Geradts et al [15]	1998	cartridge cases and the marks	pre-processing → correlation methods → Transforms
Banno et al [20]	2005	Bullet striation marks	two-stage comparison method focused on 3D geometric: i) aligned global shapes and evaluated a global shape similarity, ii) small elevations are compared by neural networks

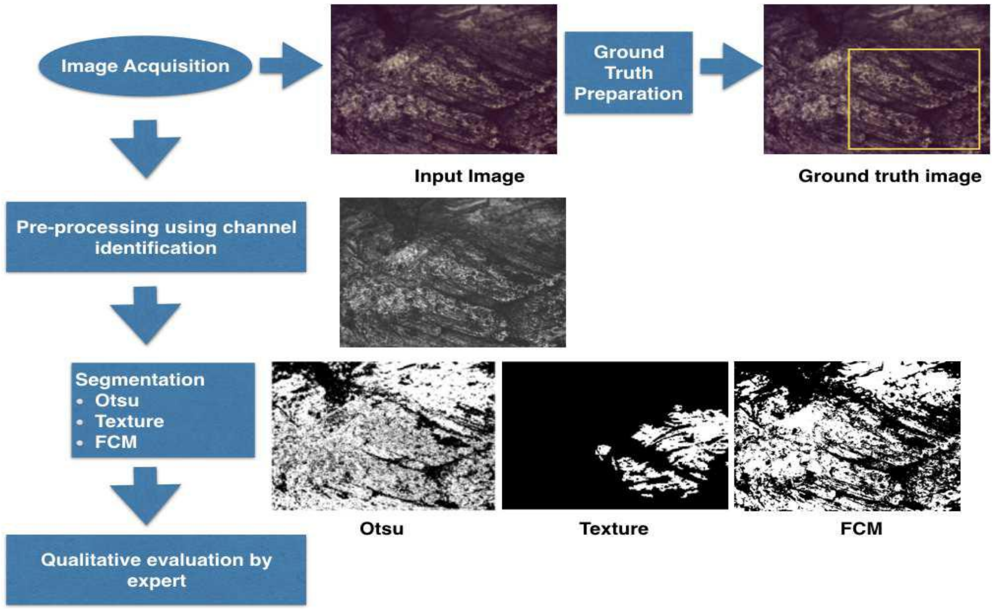

Fig. 1. Block diagram of the proposed work

III. METHODOLOGY

A. Overview of the work

The study is divided into four steps. The first step is the image acquisition and identification of RoI by a professional ballistic expert, who also prepared the ground truth for the study. The marking of the images is done by using Microsoft Paint. The second step is pre-processing of the raw images, where the best color channel for the study of the images is selected for better analysis for the next step. The third process is the segmentation using three techniques namely Otsu thresholding, Texture thresholding, and Fuzzy C Mean thresholding. This step is followed by a qualitative evaluation of results by ballistic experts to find out the best segmentation algorithm. **Fig 1** demonstrates the work using a diagrammatic representation.

B. Image Acquisition and Ground truth preparation

Ten images of two fired bullets of .22 in. caliber rimfire cartridge fired from one and the same firearm (semi-automatic pistol) were considered for the preliminary study (**Fig 2**). Images were captured using Zeiss Microscope at Central Computational and Numerical Studies Division (CCNS) of Institute of Advanced Study in Science and Technology (IASST), Department of Science & Technology, Govt. of India, Assam. The magnification of the image is fixed at 5X as it was established that this magnification gives us the most distinct striations. The size of the image in 5X magnification is 2560×1920 pixels. Then these images were sent to Ballistics Division, Central Forensic Science Laboratory, Directorate of Forensic Science Services, Ministry of Home Affairs, Govt. of India, Guwahati, for marking of ground truth.

Fig 2. Picture of bullet used in the study

C. RoI to be considered

RoI in the study is the striations on the surface of the fired bullets. Different gun manufacturers use different rifling techniques with predetermined parameters. These techniques impart the class as well as individual characteristics of the barrel on the surface of the fired (discharged) bullet. These markings leave unique striations on a fired bullet. This allows a bullet to be traced back to a particular firearm from which it was suspected to be discharged. For example, in **Fig 3** it is possible to determine the bullet on the left and the bullet on the right are from the same gun by matching the striations.

D. Image Pre-Processing (Color Channel Identification)

Selecting a suitable channel for the work is significant as not every color channel exposes the information that is required to be extracted. Microscopic images always suffer from uneven illumination Therefore different channel study always helps to extract the best channel containing maximum information.

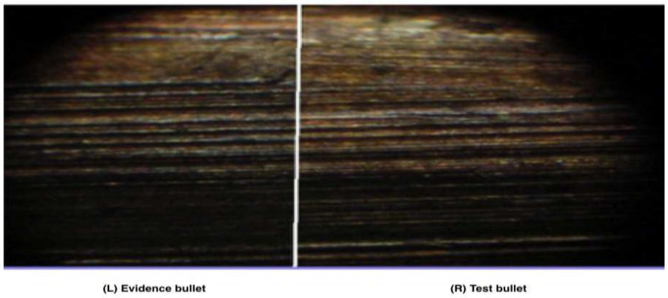

Fig. 3. Bullet comparison [16]

As RGB color channels only perform well with uniform images with homogeneous illumination, uneven illumination based information can be properly extracted using color channels like HSV and YCbCr. We have explored all the available standard color channels of the images and found that the intensity channel was best suitable for our use, as it distinctly segregated the striations from the background.

E. Segmentation

Segmentation is a process that splits the image into meaningful regions. It is one of the most important elements of a complete image analysis system. Segmentation gives us regions and objects that we may later describe and recognize. The segmentation processes are fully application specific.

Otsu: Otsu method is one of the most effective methods for image thresholding because of its simple calculation. It finds the threshold that minimizes the weighted within-class variance. Post-Otsu operation we conduct Erosion to enhance the output images. It is a morphological operation which basic effect on a binary image is to erode away the margins of regions of foreground pixels (i.e. white pixels, typically). As a result, the areas of foreground pixels reduce in size whereas the gaps within increase [17].

Texture Thresholding: One category of textural segmentation is region based and boundary based. For this study we implemented the region growing segmentation as it is one of the state-of-the-art technique used for image segmentation. It depends on the principle of homogeneity, which means there has to be at least one characteristic that remains constant for each and every pixel within a region. Region-based texture segmentation can be described by a vector of statistics which can be first order (Mean, Variance etc.), second order (describing the relation between pixel pairs) and higher order (quantize region in runs of pixels). 'Entropy' is a first order statistic, which defines how normal/non-normal is the grey level distribution. It is a statistical measure of randomness. We use *entropyfilt* to create a texture image. The function *entropyfilt* returns an array where each output pixel contains the entropy value of the 9-by-9 neighborhood around the corresponding pixel in the input image. Next we threshold the rescaled image *Eim* to segment the textures. A threshold value of 0.8 is selected because it is roughly the intensity value of pixels along the boundary between the textures [18]. The *imbinarize (Eim, .8)* is used to threshold the rescaled image *Eim* to segment the textures. Here 0.8 is passed as a parameter because it gives us the required intensity values.

Fuzzy C Mean (FCM): For this purpose, we have followed the work of Chankong et al., [19]. FCM always work well on data with uncertainty. Here patch-wise labelling of the image pixels is performed. Rather than considering every pixel value and directly cluster them into 2 or 3 clusters, we cluster the pixels into patches, where each patch is represented by its center value. Initially, the median filter is applied to the intensity channel image to reduce noise and then the FCM algorithm is applied. Then FCM centers are arranged in ascending order. For each patch, corresponding to sorted FCM centers, one threshold *Tn* is decided in accordance with the percentages of all patch centers. If FCM center of patch ≤ *Tn* then we have labelled the patch as striation otherwise that patch is considered as background. *Tn* varied from 70% to 120% in our case. The threshold that gives better segmentation results (based on qualitative evaluation) is selected as the final threshold.

IV. RESULT AND DISCUSSION

The results of channel identification are shown in **Fig 4**. As shown in the figure nine channels were extracted using color model RGB, HSV and YCbCr. Segmentation is performed on all the nine channels but the channel which is giving the best result is considered for the study. After performing pre-testing on five images it was observed that intensity channel is suitable for segmentation purpose as it highlighted the striations properly as compared to other channels. That is why the intensity channel is finalized for the study

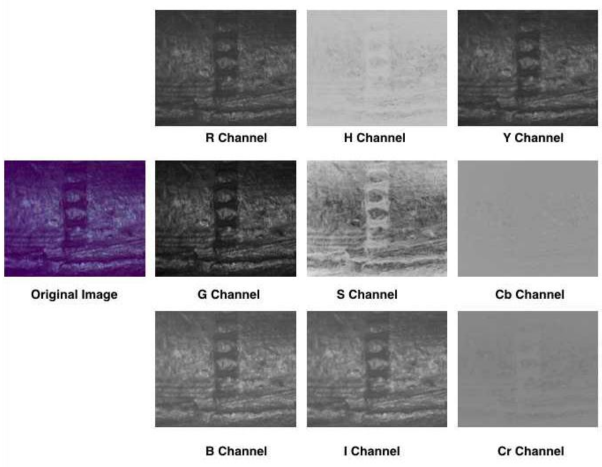

Fig. 4. Channel extraction as a part of the pre-processing operation

Visual results of the different segmentation algorithm are shown in **Fig 5 and 6**. Column 1 depicts the original image. Column 2 shows the ground truth image. Column 3 shows the result of segmentation using Otsu thresholding (Approach 1), Column 4 displays the result of segmentation using texture thresholding (Approach 2) and the last column gives the result of segmentation using FCM (Approach 3). Then, qualitative evaluation of the outputs obtained from three approaches was analyzed by ballistic experts. They mainly focused on the area marked in the ground truth image. Finally, it is observed that Approach 3 (using FCM) is giving a better result as compared to the other two approaches. It can extract maximum striation marks in the RoI marked in ground truth. This is a preliminary study on automated segmentation. In the future, we will try to extract the patterns of the striations and also perform bullet matching. This work is undergoing in CCNS, IASST in collaboration with CFSL, Guwahati.

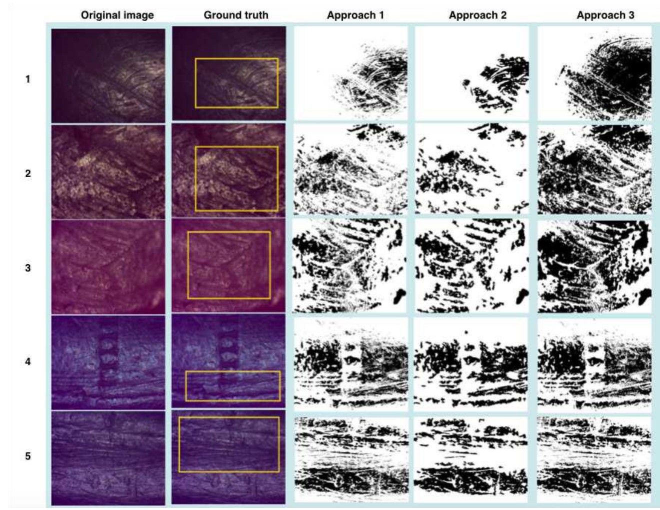

Fig.5. The result of segmentation for images 1 to

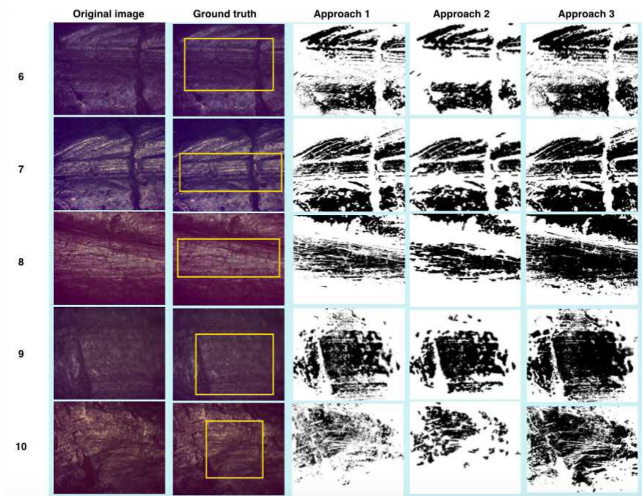

Fig. 6. The result of segmentation for images 6 to 10

V. FUTURE WORK

This is a preliminary study on automated segmentation. Striation marks on fired bullets are a highly challenging field for image processing because first of all successful image acquisition of the very scanty striation area is difficult. Secondly, these images are very highly noisy. Finally, there are very few striation images of bullets to depend on, to develop efficient algorithms. However, the present study motivates us to carry on the research to develop more efficient algorithms for clearing out the noise to a higher extent, so that a complete and automatic segmentation of the striation patterns can be achieved. Moreover, if a database of striation mark of different firearms can be made available/developed, the segmented images may be classified by using pattern recognition techniques too.

VI. CONCLUSION

Experimental results show that the image processing system can be used for firearm identification efficiently and precisely through digitizing and analyzing the fired projectiles specimens. This could be of immense use in the future as it is a real-time saving process. A proper algorithm can be developed which can create a database for firearm identification. As crimes are a menace in society, the design and development of an efficient and robust system for identification of firearms involved in the crimes, with the help of image processing techniques, can assist in making the society a safer place to live in by identifying the perpetrator of the crime as soon as possible and assisting in judicial process. Moreover, if a database of striation mark of different firearms can be made available/developed, the segmented images may be classified by using pattern recognition techniques too.

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Authors Profile

Dr. Lipi B. Mahanta is an Associate Professor working in the Central Computational and Numerical Sciences Division of Institute of Advanced Study in Science and Technology, Guwahati, Assam, India. She obtained her Ph.D. degree in Statistics in 2004 from Gauhati University, Guwahati, Assam. After collecting experience as a teacher of Computer Science for more than 20 years she started research work in different areas of Image processing, Pattern Recognition, and Machine and Deep Learning. She has published more than 60 papers in national and international journals in these various fields

Dr. Kangkana Bora is an Institutional Post Doctoral Fellow in Indian Institute of Technology Guwahati (IITG), Assam, India. She has received her PhD degree in IT from Gauhati University in 2019. She obained M.Tech degree from Gauhati University and B.Tech (IT) degree from North Eastern Hill University, Meghalaya, India. Her research Interset is in Bio-medical Image processing, Computer Vision and Machine learning. She has more than 13 publications in esteemed journal and conferences.

Rahul Kumar is a B.Tech student of Assam Engineering department, Assam, India. His research interest is Image Processing.

Shauvik Purkayastha is a B.Tech student of Assam Engineering department, Assam, India. His research interest is Image Processing.

Sh. R. Suresh is Assistant Director & Scientist 'C' (Ballistics) of the Central Forensic Science Laboratory, Directorate of Forensic Science Services, Ministry of Home Affairs, Government of India, Guwahati. He research interests are in different areas of ballistics, with publications in improrant journals.

