A Proposed method of Edge Detection from Impressions of footwear found in crime scenes

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***Abstract*— It is time consuming for analyzing wide variety of footwear impression because of different types of footwear outsole designs. The forensic footwear experts faced two types of problems -(1) to determine the source of an impression given a known set of outsole prints where there are no known prints to match, and (2) to determine whether a particular impression evidence is from a known suspect's shoe with similarity and uncertainty. This paper proposed the work for edge analysis of impression from footwear. Successful, high quality crime scene investigation is a simple, methodical process. It is not rigid; it follows a set of principles and procedures that are reasonable and ensure that all physical evidence is discovered and investigated with the result that justice is served. The basic crime scene procedures are physical evidence recognition, documentation, proper collection, packaging, preservation, and, finally, scene reconstruction. Every crime scene is unique and, with experience, a crime scene investigator will be able to use this logical and systematic approach to investigate even the most challenging crime scenes to a successful conclusion**.

***Index Terms*— Shoe Print, EDA, and BHEA.**

I. INTRODUCTION

Footwear impressions are among the most commonly found evidence at crime scenes and present more frequently than finger prints. Identification is based on the physical match of random individual characteristics of the shoe has acquired during its life. The only thing consistent about crime scenes is their inconsistency. Because of their diversity, crime scenes can be classified in many ways. First, crime scenes can be classified according to the location of the original criminal activity. This classification of the crime scene labels the site of the original or first criminal activity as the primary crime scene and any subsequent crime scenes as secondary. This classification does not infer any priority or importance to the scene, but is simply a designation of sequence of locations. Evidence provided by a positively identified shoe mark is as strong as the evidence from fingerprints, tool marks, and typewritten impressions [1]. Detail retained in a shoe mark may be insufficient to uniquely identify an individual shoe but is still very valuable. Due to the wide variety of shoes available on the market, with most having distinctive outsole patterns, this implies that any specific model of shoe will be owned by a very small fraction of the general population. Furthermore the same outsole pattern can be found on several different footwear brands and models. If the outsole pattern of a shoe can be determined from its mark, then this can significantly narrow the search for a particular suspect. The current practice is that forensic examiner collects and preserves footwear and tire tread impression evidence for makes examinations, comparisons, and analyses in order to identify or eliminate a shoe, or type of outsole, as the source of an impression, determine the brand or manufacturer of the outsole or footwear, link scenes of crime, and write reports and provide testimony as needed. A study of the variation of bloodstain patterns formed by footwear impression on different textured surfaces (i.e. plain/smooth, rough, porous etc.) they have also provided valuable insights on how bloodstain patterns vary with difference in impact angle , fall height , target surface properties, quantity of blood etc. Footwear impression evidence could also be effectively used to support or contradict the probable reconstruction put forward by an expert witness. Based on photographic impression Forensic analyst requires comparison of this image against specific databases. These databases include: (i) marks made by shoes currently and previously available on the market and (ii) marks found at other crime scenes. Normally an image of a shoe mark can be obtained using photography, gel, or electrostatic lifting or by making a cast when the impression is in soil [2]. Subsequently, in the forensic laboratory, the image of the shoe mark is compared with the shoe-prints and shoe impressions of known shoe samples. Interactive image enhancement operations are used in Photoshop and other image processing software that are available to the footwear examiner. Footwear images collected directly from crime scenes are of poor quality. The environment under which the questioned shoe print is lifted at the crime scene is different from those available in the known prints. One approach is to design digital image enhancement techniques, such as contextual thresholding, to enhance the quality of questioned shoe-prints to achieve feasibility of matching shoe-prints in the database. Debris and shadows and other artifacts in the crime scene impressions are difficult to alter out from footwear impressions. They have interfered with attempts to store and search in the database. Therefore, after digital image enhancement, some algorithms are desired to be able to classify different regions of footwear impression to be one of two types: useful regions (impressed by footwear) and discard able regions (impressed by other artifacts such as debris). An automatic footwear identification system accepts as input shoe-print evidence and retrieves the most likely matching prints. Automated software for footwear impression analysis points to [3-5]:

Manuscript received Dec 15, 2014

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1. Develop or identify suitable image processing algorithms to enhance the quality of the images for further processing.
2. Evaluate or develop feature extraction methods that are; (i) suitable for describing geometrical patterns in outsoles and (ii) are robust in processing poor quality crime scene images.
3. Develop similarity measures for the comparison of footwear prints based on the features extracted such as edge detection and segmentation.

II. Proposed Edge Detection Methods

Digital image technology provides a crime scene investigator with powerful new tools for capturing, analyzing, and storing records of the crime scene and its physical evidence. These digital imaging tools complement the traditional video and still photography used in crime scene documentation. The advantages of digital images include instant access to the images, easy integration into existing electronic technologies, and no need for expensive film processing equipment and darkrooms. Disadvantages in using digital image technology center on issues of court admissibility because of easy image manipulation. However, it is important to remember the investigator testifies and the image does not. Written and implemented policies and procedures for using digital images can eliminate the disadvantages. The law enforcement community agrees that digital imaging in crime scene documentation can best be used as a supplemental technique and not completely replace the traditional techniques. Volunteers were asked to step on talcum powder and then onto a carpet to create a simulated crime scene print. Their prints were also captured on chemical paper to create the known. Both were converted into digital camera images.

In preprocessing some basic image enhancement and noise reduction techniques are implemented. Apart from that different ways to detect edges of footwear and doing segmentations have also been used. The purpose of these steps is basically to improve the image and the image quality to get more surety and ease in detecting the footwear impression for crime scene reconstruction. The basic steps in preprocessing are the following:-Image is converted to gray scale image in first step. Noise is removed if any. The obtained image is then passed through a high pass filter to detect edges. Then obtained image is added to original image to enhance it.

In processing the following steps are followed:-Segmentation is done on basis of a threshold, due to which whole image is converted into binary image. Basic Matlab commands for threshold are used for this segmentation. It is the best method to segment an image to separate image of footwear but it suffers from over and under segmentation, due to which we have used it as a check to our output. We have not used watershed segmentation on our input, rather it is only used on our output to check of the result is correct or not. Morphological operations are applied on the image after converting it into binary form. The basic purpose of the operations is to show only that part of the upper part and lower part of footwear image.

In a computerized tool to assist in identification, firstly, known shoe-prints are scanned, processed and indexed into a database. The collection of test prints involves careful human expertise in order to ensure the capture of all possible information from the shoe-print. All such information is indexed into a database so as to be matched against shoe-print evidence. An automatic footwear identification system accepts as input shoe-print evidence and retrieves the most likely matching prints. In this paper we segmented shoe print and then find the edge of the shoe print image for analyzing foot print patterns.. The impression of a piece of footwear can potentially lead to 3 identifications, of increasing accuracy; a shoe of a certain size, a shoe of a certain make or a specific shoe. The quality of the print will usually dictate which of these is possible. A vague outline is unlikely to provide conclusive evidence, but could offer some information about the size, and in some cases the brand of a shoe. A high quality print that reveals defects and shape-differences specific to an individual's shoe is very rare, and the fact that there will only be one sample of any specific shoe means the chances of a conclusive classification here is low. The most common type of recognition will be that of the shoe's make and model, due to the availability of this data (from shoe manufacturers), the number of samples and the ability to classify according to identifiable features.

The detection of edge in shoe print images is done in two phases. In the first phase the image is homogenized and the color is quantized to a set of sixteen color gray scale palette. This process is carried out in both x direction (horizontal) and in the y direction (vertical) so that the image is homogenized in both directions. Then we detect the edge by traversing the image in two passes to obtain the horizontal and vertical edge points. The final edge map is the union of edges obtained in the two passes. In this research paper we have proposed a new homogeneity enhancement process namely Binary Homogeneity Enhancement Algorithm (BHEA) for digital foot print image. In this process, the image is treated as an array of pixel data. First step of the process is to determine the dimension of the image and determine the middle position of image array. We then take a maximum difference threshold (MDT) value i.e. $\pm \Delta d$, which is constant threshold determine by the intensity of the image. The homogeneity process is done in two passes. In the first pass the image is scanned in horizontal direction considering each row from the first row till the last row of the image. In the next pass the same process is repeated in the vertical direction by considering a column wise scanning, starting from first column till the last column of the image.

The algorithm starts by checking intensity values from the image data by horizontally scanning from leftmost pixel of a row of a two dimensional pixel array to the rightmost pixel of the same row. The algorithm considers one row of image data at a time and after completing the operations iterates to the next row and continues till the last row is reached. If the result of any subtraction is greater than the MDT, the one dimensional pixel array constituting the row will be divided into two equal subsets along the middle position (M).$P_{x,y}$ is the position of pixel.S1 and S2 are one dimensional arrays containing values of pixel in a single dimension matrices.

$$|P_{x,y} - P_{x+1,y}| > \Delta d \qquad (1)$$

$$M = P_{x+n,y} - P_{x,y}2 \qquad (2)$$

$$S1(P_i \ldots M)\ ,\ S2(M+1 \ldots P_n) \text{ where } I = x \text{ to } n$$

The first subset containing pixels from the first position till the middle position and the second subset containing pixels from middle position till the last position will be pushed to a stack. Otherwise, the statistical mode value of image intensity of the pixels within the subset will be propagated to all the pixels within the current subset of pixels. This is done after modifying intensity value using uniform color quantization technique to obtain quantized value (Q) in color space breaking in sixteen level scales. The statistical mode value is taken as the image intensity of surrounding pixels is prevalently of similar intensity with only few pixels are dissimilar. The central tendency is better represented by the statistical mode operation.

Where Mode = $fmax(\Sigma Pix+ni=x)$ (3)

$Q = Mode/16$

$f(B) = \Sigma(Pix+ni=x=Q)$ (4)

The process will be continued, popping the subset of arrays from the stack and repeating the aforesaid process. The process will be continued until the stack is empty.

$f(Mif(B)) = f(Mi\ f(B)),f(Mi+1f(B)), \ldots f(Mnf(B))$ (5)

In the next pass the same process will be repeated by scanning the image vertically from top to bottom considering each individual column, from first column till the last column in the two dimensional pixel array representing the foot print image. The algorithm considers one column of image data at a time and after completing the operations iterates to the next column and continues till the last column is reached. If the result of any subtraction of image intensity is greater than the MDT, the one dimensional pixel array constituting the column will be divided into two equal subsets along the middle position (M).

$|Px,y - Px,y+1| > \Delta d$ (6)

$M = Px,y+n-Px,y2$ (7)

S1(Pi … M) , S2(M+1 … Pn) where i=x to n

The first subset containing pixels from the first position till the middle position and the second subset containing pixels from middle position till the last position will be pushed to a stack. Otherwise, the statistical mode value of image intensity of the pixels within the subset will be propagated to all the pixels within the current subset of pixels. This is done after modifying intensity value using uniform color quantization technique to obtain quantized value (Q) in color space breaking in sixteen level scales. The statistical mode value is taken to obtain the central tendency as provided by the equation (3).

$f(B) = \Sigma(Piy+ni=y=Q)$ (8)

The process will be continued, popping the subset of arrays from the stack and repeating the aforesaid process. The process will be continued until the stack is empty.

$f(Mif(B)) = f(Mi\ f(B)),f(Mi+1f(B)), \ldots f(Mn\ f(B))$ (9)

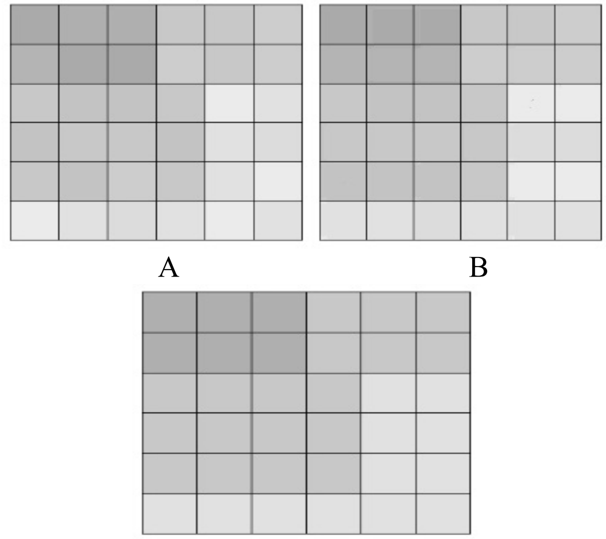


Figure. 1. (a) Showing a 6X6 pixel 2-D array with different intensities, (b) The 6X6 pixel 2-D array is homogenized in horizontal direction in first pass of algorithm, (c) The final 6X6 pixel 2-D array after homogenized in vertical direction in second pass.

The resultant image obtained after the two passes of the algorithm represents the shoe print image that has homogenous regions that is color quantized to sixteen-color in gray scale. This image forms the input image for the edge detection process.

After the image was processed by the proposed Binary Homogeneity Enhancement Algorithm (BHEA) we obtain an image that is homogenous and have pixels in gray scale of sixteen level scales. This image forms the input for the next level of processing for detection of the edge, i.e. footwear boundary and the footwear region. In this research paper we have proposed a new method for detecting edge rather than using one of the known methods of edge detection that uses a convolution filter.

The edge detection process is done in three passes. In the first pass the scanning of image is done horizontally in the x direction i.e in a row major order. The algorithms start from the leftmost pixel of the first row and traverse all pixels on the first row to reach the last pixel of the first row. Then we repeat the scanning of pixel from the next row and continue to subsequent rows till we reach the last pixel in the last row of the two dimensional image data array. An adaptive threshold value (Δt) is taken for pixel intensity comparison. The threshold value changes depending on the intensity of the pixels in the surrounding region. During the scanning of pixels the algorithm compares the intensities of subsequent pixels. If a change in intensity is observed between two pixels that exceed the absolute threshold value then the algorithm marks the last pixel as edge and adds this pixel location to the horizontal edge map image.

$f(h) = \Sigma\Sigma|Px,y-Px+i,y|ci=0rj=0>\Delta t$ (10)

The algorithm now continues the scanning of image vertically in the y direction i.e. in a column major order. The algorithm starts from the topmost pixel of the first column and traverse all pixels on the first column to reach the last pixel of the first column. Then we repeat the scanning of pixel from the next column and continue to subsequent columns till we reach the last pixel in the last column of the two dimensional image data array. The same technique of adaptive threshold value (Δt) is taken for pixel intensity comparison. During the scanning of pixel the algorithm compares the image intensities of subsequent pixels. If a change in intensity is observed between two pixels that exceed the absolute threshold value then the algorithm marks the last pixel as edge and adds this pixel location to the vertical edge map image.

F(v) = ΣΣ⍰Px,y−Px,y+i⍰ri=0cj=0>Δt (11)

Finally, in the last pass we merge the Horizontal Edge Map image with Vertical Edge Map image by performing a Union operation on the two image files, to obtain the Edge map of mammogram image. The edge image obtained uniquely contains single pixel continuous edge line as a result we need not perform further edge thinning process. The edge line is continuous so the process of edge linking is also not required.

EdgeMap = f(h) U f(v) (12)

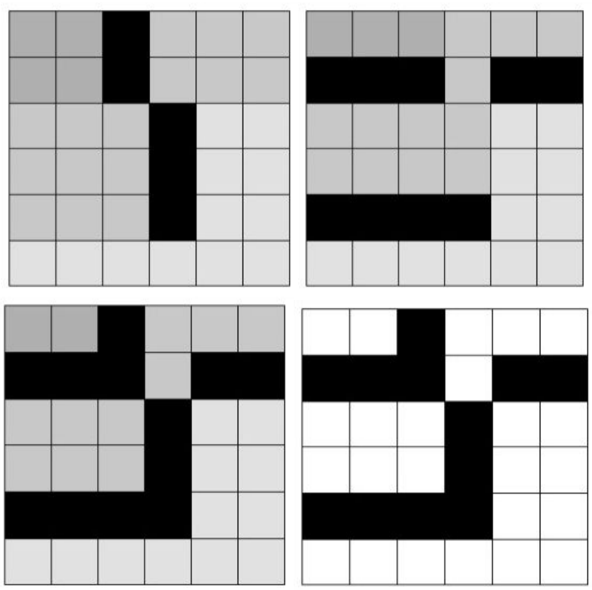
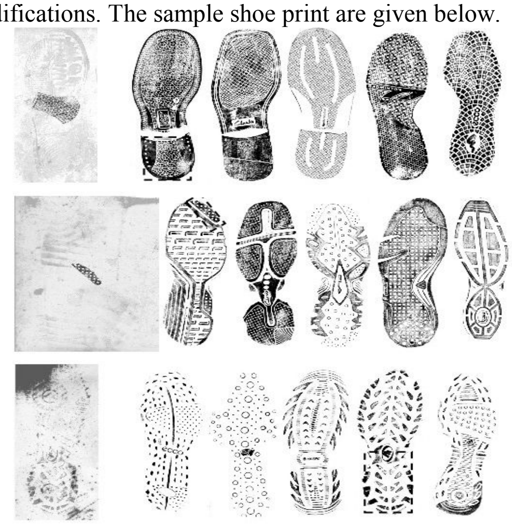


Figure. 2. (a) The 6X6 pixel 2-D array of image after performing the first pass of EDA showing horizontal edge map image, (b) The 6X6 pixel 2-D array of image after performing the second pass of EDA showing vertical edge map image, (c) The 6X6 pixel 2-D array of image after performing the Union showing complete edge map image, (d) The final output of EDA with edge map image on a white background (Monotone image).

Some edge-detection operators are instead based upon second-order derivatives of the intensity. They essentially capture the rate of change in the intensity gradient. Thus, in the ideal continuous case, detection of zero-crossings in the second derivative captures local maxima in the gradient. In order to effectively detect intensity changes (edges), the operator needs to have two characteristics. First, it must be a differential operator, taking either a first or second spatial derivative of the image. Second, it should be capable of being tuned to act at any desired scale so that large filters can be used to detect blurry shadow edges, and small ones can be used to detect sharply focused fine detail in the image. This led to the so-called Laplacian-of-Gaussian edge operator.

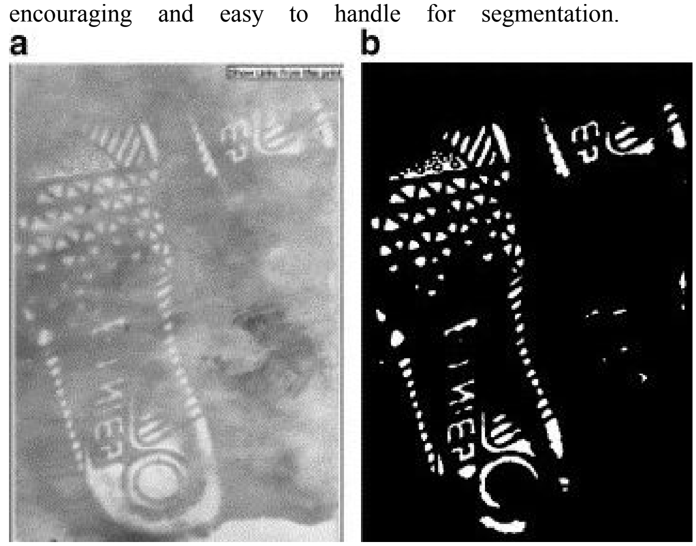
The edge map image is mostly free from any noise that is observed in other known methods of edge detection. It can be observed from the edge map image that each region of the foot print in a image is clearly visible. The edge detection process has also separated the foot print boundary from the exterior non foot wear region. The edge map image also clearly demarcates the imprint region thus making it easier to obtain the region of interest. Abnormal region or other abnormalities if present within the image is clearly visible and forms closed objects that can be easily isolated from the image. With this edge detection method, the image segmentation process becomes very easy as most of the region is already isolated by the process. This edge detection method is simple, fast as it does not require convolution, robust and can also be implemented to other medical imaging with little modifications. The sample shoe print are given below.



Sample shoe prints and features (Image from [3])

III. Results

The proposed edge detection method is tested over a number of samples and result is found as follows. The result is encouraging and easy to handle for segmentation.



Noisy sample and result of edge removal using proposed technique. (Image and equation above from

CONCLUSION

The proposed algorithm produces edge map image that uniquely contains single pixel continuous edge line so edge thinning process is not required. The edge line is continuous so the process of edge linking is also not required. The edge map image is free from any noise that is observed in other known methods of edge detection. It can be observed from the edge map image that each region of the foot print is clearly visible. With this edge detection method, the image segmentation process becomes simple. This method is simple, efficient as it does not require convolution, robust and can also be made useful for other medical imaging with little modifications.

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