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Analysis of Footprint in a Crime Scene

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Abstract

Violent crime scenes often register incomplete/broken bloodstained footprint impressions. It is often difficult to make predictions from broken footprints obtained from a crime scene. Though it is easy to differentiate a complete footprint from a complete shoeprint, such differentiation does not stand easy when attempt is made to distinguish an incomplete footprint from an incomplete shoeprint owing to large variation in foot size, shoe size and shoe make. Hence, this study is an attempt to develop a computer based methodology that uses MSER features and available contour of prints to differentiate between an incomplete bloody shoe and footprint. When tested on a dataset of 237 prints, a footprint/shoeprint classification accuracy of 81 % was achieved (Sensitivity- 79.6% and Specificity and 76%).

Keywords: Footprints, Identification, Shoeprints.

Introduction

Forensic analysts have a major role in crime investigation. They examine the crime scene and collect the marks and evidence which are left by accused and victim. Footprint is a very common and important mark in the crime scene. It helps to draw important conclusions about individuals who were present at that arena during the crime. Analysts examine the footprint in real time, it is 3D view and they also capture images for future reference and subsequent examination. 'Capturing Image' process transfers the 3D shoeprint into 2D and the real time essence is lost. There are definite rules which are followed by professional photographers, as the captured images can be used for forensic analysis.

There are several types of footprint, one is called *latent* print which is not visible to bare eye. When a person walks on a floor and both the floor and his/her foot are dry, the produced footprint is known as latent print. Another type of print is *visible* print or *patent* print, wet soles of feet on a dry floor will produce it. This type of print is visible to the bare eye and very effective for investigation purpose. In case of *impressed* prints foot impressions are left on soft, pliable or particularly impressionable surface such as clay surface, molten wax surface and the like. These impressions are also visible to the naked eye and can be viewed or photographed without development[1].

In a populous country like India where crime is not very rare, manual analysis is very time consuming process. According to the records of National Crime Records Bureau in 2012 total number of violent crimes in India was 275165 in which 25 percent were gone to the conviction stage[2]. Delay in investigation process affects the judgment procedure and increases the number of filed cases. So an automated system will be very helpful towards hastening up the crime scene reconstruction process. From footprint several information,such as size of foot, presence or absence of shoe, direction of motion, style of stepping, sex, and stature of the concerned person can be predicted. Proper and quick prediction of these information by an automated system shall help constrain the investigation boundary and will lead to correct, efficient investigation.

In a crime scene there may be different types of footprint. This research work particularly deals withvisible prints or patent prints. Visible prints produced when any surface (in this case foot or shoe) comes in contact with blood are commonly referred to as Transfer Stains. Thorough study of the images of this type of stain by an automated system will be very useful for the investigating agency.

The automated system is a CAD (Computer Aided Diagnosis) system based on three key steps – i>Pre-processing of the image ii>Feature Extraction iii> Classification. Performance of classifier is very much dependent on the robustness of feature set. So construction of a strong feature set is very important, it increases the performance index of the automated system[3].

Review Works: Footprint is an important mark in crime investigation. Several studies have shown that dimension of foot and footprint is a very good indicator of stature and gender of a person. Correlation coefficient and regression analysis are very important part of those studies.

Two groups are formed – male and female belong to specified range of age. More or less equal numbers of male and female are considered as sample points. Different parts of India are reflected in the studies like North Indian adolescent people, Gujjars of North India, indigenous people of North Bengal.

Ozden et. al. analyzed 294 male and 275 female footprint samples. In his work he reported significant correlation in stature and right shoe length (r=0.591). The correlation coefficient(r) between stature and right foot length as also between stature and right shoe length was predicted to be 0.579. For female subjects in the study positive correlation between stature and right foot length as also between stature and right shoe length (r=0.460) was recorded. The study had a prediction accuracy of 86-98%[4].

Kewal Krishan conducted a study on a sample of 2080 bilateral footprints and foot outlines collected from 1040 adult male Gujjars of North India. The age group of the male subjects ranged from 18 to 30 years. The highest positive correlation coefficient was recorded for toe length measurements (0.82-0.87)[5].

Gender identification/prediction with 95.6% accuracy was recorded for right foot measurements and 96.4% accuracy was recorded for left foot measurements by Zeybek et. al. About 249 students who were attending Medical Faculty of Dokuz Eylul University and School of Physical Therapy and Rehabilitation in Turkey took part in the study[6].

Jaydip Sen and Shila Ghosh undertook a study on stature, foot length and foot breadth of 350 adult Rajbanshi and 100 adult Meche individuals (age range: 18-50 years) residing in different villages located in the Darjeeling district of West Bengal. The study reported 92% prediction accuracy[7].

In these studies the height and width of feet are recorded, then the mean are calculated and then based on these values standard deviation of height and width are measured. Then based on these values correlation coefficient is calculated and regression analysis can be done to predict the stature, sex of the person whom the footprint belongs to.

The footprints in crime scene have some problems. Maximum of the footprints are broken – so it is often difficult to measure the height and width of the footprints accurately. So some reconstruction procedure should be adopted to get the accurate measure of those parameters. Then subsequent steps for prediction could be applied.

Human experts apply their experience to distinguish the footprints in two sets; bare footprint and shoeprint. Then the corresponding reconstruction and mathematical techniques can be applied on the captured images for prediction.

For the automated system situation is not so easy, system has no experience. So it cannot differentiate the bare footprint and shoeprint automatically. For applying the reconstruction and mathematical procedures system has to identify these two types of print properly. Here an attempt has been made to develop a method which can be applied for automatically differentiating those two sets. Then the next steps can be incorporated in the system, thereby making the extended system useful for the investigation purpose.

Methodology

Sample blood-stained footprints are created on herbarium sheet, and then those are dried up. After that according to some basic rules of Forensic Science the images of the sample footprints are captured from a fixed focal length at perpendicular direction by a high resolution camera. Two scales are placed horizontally and vertically along the edge of the image to detect any type of distortion of the footprints in the image.

There are some noise and artifacts in the images. These should be removed for proper differentiation of the foot and shoe prints. The actual image matrix of the blood-stained footprint is cropped from the whole image by removing scale artifact and other background noises. This operation is known as pre-processing of the image which is prerequisite for further processing of the image. These are the steps:

Create a RGB image set by reading all the images from the database. For each image identify and extract the red portion of the image which is the Region of Interest (ROI). Create different channel matrices for red, green and blue component. For each pixel of the image determine the larger component between green and blue. Take away this from the red component. If the calculated value is less than α, it indicates that the pixel is not red. Otherwise this pixel is considered in ROI. Apply wiener filter with window size 3×3. Consider the regions consist of equal or more than β pixels. Noise free Binary image set is obtained from the RGB image set by performing these operations. Database consists of images with 500×500 resolution. So 3×3 window size of wiener filter is enough. Applying trial and error method it is observed that 10 and 26 are appropriate as the values for 'α' and 'β' respectively for this current study. The cropping is done by applying the following steps on the binary images: Scan the image from the left in column major order. First pixel with value zero is marked as the left boundary of ROI. Scan the image from the right in column major order. First pixel with value zero is marked as the right boundary of ROI. Scan the image from the top in row major order. First pixel with value zero is marked as the top boundary of ROI. Scan the image from the bottom in row major order. First pixel with value zero is marked as the bottom boundary of ROI.

Now the cropped image set is ready for further processing. Here the size of the images is much less than the original images, hence the proposed method for partitioning into two sets executes faster on these images.

Now every cropped binary image is checked whether it is a bare footprint or shoeprint. The top most point and bottom most point of every image has been stored. Consider a hypothetical straight line between these two points, the boundary points of the footprint to the left of this line is considered as *left boundary points*, similarly there are the *right boundary points*.

The image is segmented into three equal parts along the height of the image. For every segment a checking is done whether the values of left boundary points and right boundary pointsare increasing or decreasing. There are flags, one flag for eachsegment for each boundary. Flag contains one when value for that segment decreases, otherwise it contains zero. In case of left bare foot it is clear that the flag values of the middle segment for both the boundaries must be zero and zero irrespective of top and bottom segment and it will be one and one for right bare foot. For shoe these flag values should be one and zero. These are shown in Figure-1 and 2.

Now for every image total number of MSER features are calculated and stored[8]. For shoe it is observed that the flag value for second segment of the left boundary decreases, for right boundary it increases and total number of MSER features is greater than or equal to 40. Increment of both flag values and less than 39 MSER features identify a bare footprint. Here are the steps of the proposed method applied on each image of the dataset:

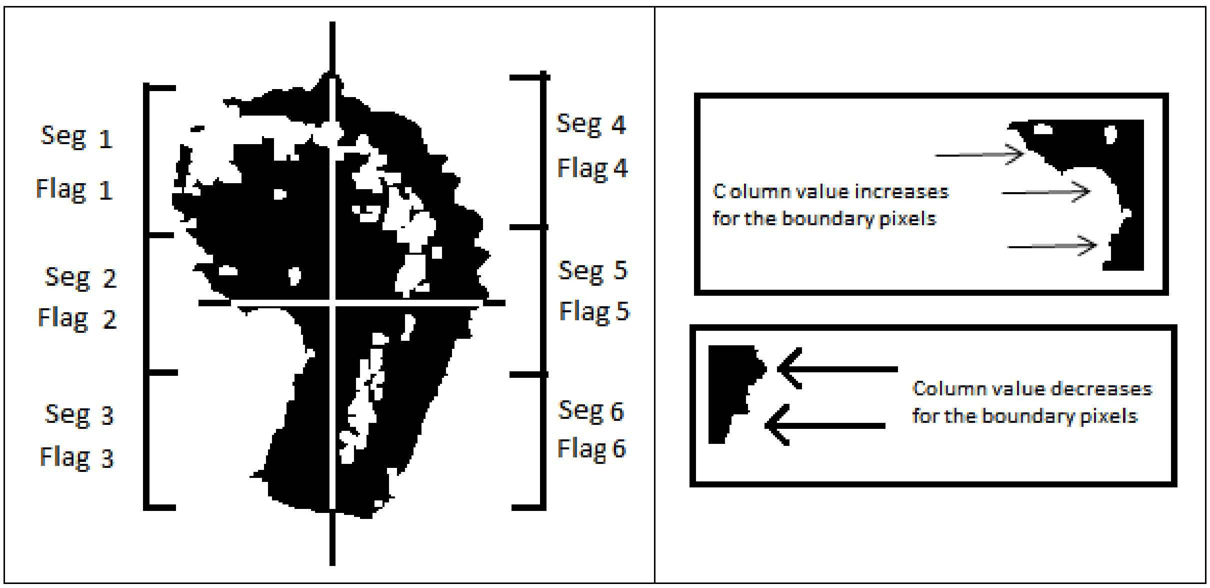

Figure-1
Detection of bare footprints

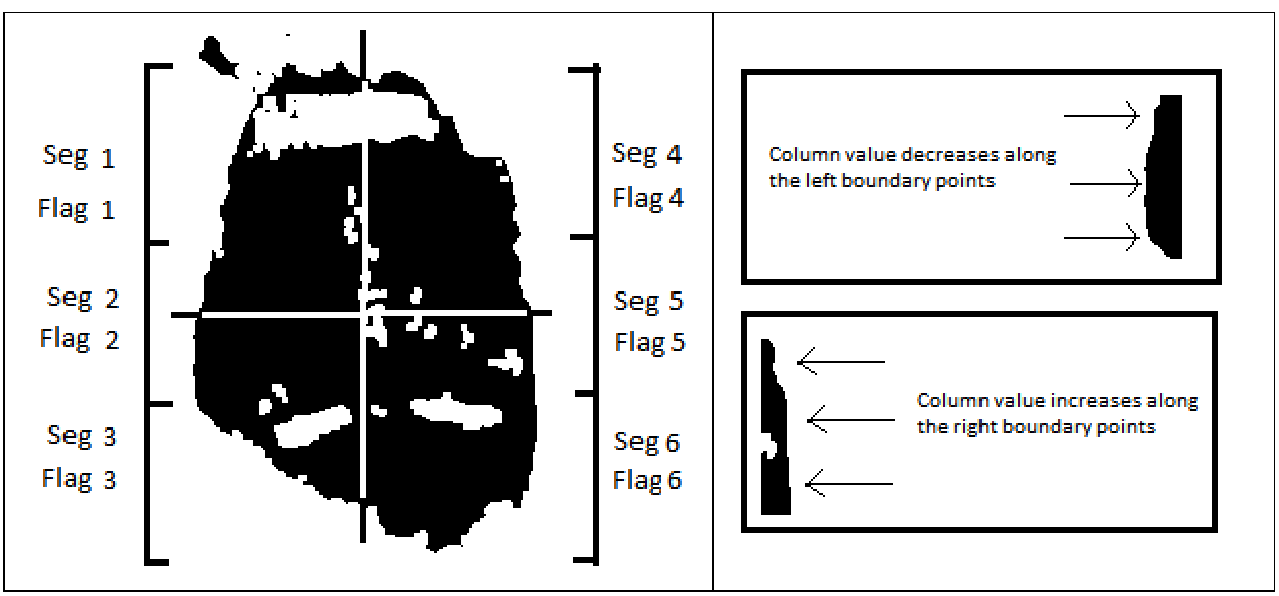

Figure-2
Detection of shoeprints

Store the left boundary points and the right boundary points of the cropped binary image. Divide the image into three segments. Check whether the boundary points value increases or decreases. Consider a flag for every segment for both the boundaries. For left boundary the corresponding flag value is zero for increment of the value of that segment, otherwise it is one. In case of bare footprint both flags of the middle segment contain zero irrespective of the top and bottom segment. For shoeprint it is one for left boundary and zero for right boundary. Calculate and store MSER features for each cropped images. Decrement of flag value for left boundary, increment for right boundary of the middle segment and more than 40 MSER features identify a shoeprint. Increment of flag value for left and right boundary of the middle segment and less or equal to 39 MSER features identify a bare footprint.

Results and Discussion

The dataset consists of 237 images of footprints of male and female. Both type of prints i.e. bare footprint and shoeprint are present there. Every image is of size 500×500 pixels and 300 dpi (dots per inch). Figure-3 is a bare footprint and Figure-4 is a shoeprint. Applying the pre-processing methodology on these two figures, the following figures (Figure 5 and 6) have been obtained. These are the cropped binary images.

Figure-3
Bare footprint

Figure-5
Pre-processed image of figure-3

Figure-4
Shoeprint

Figure-6
Pre-processed image of figure-4

Conclusion

This identification procedure may be a prerequisite for an automated system predicting the stature, gender and other parameters from footprint images. Reconstruction of a broken footprint image will upgrade this discriminating procedure. For images with bigger resolution optimum solution can be devised.

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