Partial Footprint in Person Identification

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Abstract
Person identification has really advanced with advancement in technology; whereby every feature of the body is reckon to be very important in identifying a person as their characteristics are usually unique to the bearer. The use of foot print which is one of the body features in person identification is inexhaustible, as much had not been done with it compared with other body features. Considering the various research works that has been carried out on footprint, its certain that individuals can be traced to their prints, an aspect that research works have not really considered is the possibility of tracing a partial footprint to a person especially in case of crime scene or accident. Hence this work considered identifying individuals with partial footprint by designing and implementing a person identification system based on partial footprint. The method employed involves gathering footprints from volunteers and making the prints go through image processing techniques. The images were denoised and enhanced using Gaussian filters and K-means clustering, the features were extracted using principal component analysis. The extracted features from partial foot print were matched with those of whole footprint for similarities. The efficiency of this system was tested using time taken and standard performance metrics of Receiver Operating Characteristics, where 200 samples were used and 145 matched returning true positive. There is no false negatives and this means 100% specificity which can be interpreted as having perfect classification. Hence it is concluded that the system is reliable.

Keywords:
identification, body features, foot print, images, image processing technique

1. Introduction

Diverse technological approaches have been employed in time past for person identification. Identifying people or person especially at crime or accident scene is still a major riddle that requires securing and gathering as many information traceable to person as possible Identifying individuals involve the use of unique body parts such as hair, teeth, iris, eyelids, finger prints, blood vessels, nose, palm prints, footprints and some others that are likely hidden. Also body fluids can be used to trace or identify people such as sweats, blood, semen and others especially in crime scenes, body odour and some other body features are made use of nowadays in person identification (Dwayne, 2000). Quite a number of research had been carried out on most of this body features, some are in use in places for identification, authentication and access control, the finger prints is the most widely used body part for identification as well as the eyelids and iris in facial recognition systems. Footprint which is one of the unique body parts is not left out, it is in use for person identification but the footprint identification system can be reckoned to still be in its embryonic state.

Adetunmbi and Osisanwo in 2013 considered the relevance of foot print in crime suspect identification, foot print has been identified as a reliable means of identifying crime scene suspect, since it is natural for any criminal to walk into a crime scene. Criminals are said to be getting smarter by wearing a facial mask to prevent their faces from been seen, and wearing hand gloves in other not to leave behind finger prints. Unfortunately, most are unaware of their footprints as evidence traceable to them. Hence, the importance of foot prints in person identification most especially in crime scene investigation.

The human foot print has been described as inimitable, and analysed as a body feature suitable for forensic analysis, as foot print was identified to be unique to each individual. (Osisanwo, Adetunmbi and Alese, 2014). Person identification via foot wear and barefoot print appears to be inexhaustible. Quite a lot of research works had been carried out on this, yet not everything has been covered. Using footprint in identification involves analysing the characteristics of footwear comparing with body weights, also analysing barefoot morphology for possible person identification. Some research works have been carried out on the use of

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footprint for identification these include the works of Robert et al in 2005; Lesley and Robert, 2009; Sargur 2010, Adetunmbi and Osisanwo, 2013, Osisanwo, Adetunmbi and Alese, 2014; and so on. Reviewing these works made it known that there is little or no consideration for identification through partial foot print. Partial foot print can be very valuable in solving crime scene riddle or for accident victim identification. Also the availability or accessibility of pressure sensing floors in developing countries was not considered. Hence this paper considers the possibility of person identification with partial footprint using manual method of gathering data set.

1.1. The Research Objectives

The specific objectives of this research includes

i. Design a partial footprint person identification system using image processing technique
ii. Implement the design in (i), using Java programing language, Mysql, PHP, and apache webserver.
iii. Evaluate the efficiency of (ii) using standard performance metrics

2. RELATED WORKS

Kumar and Ramakrishman, 2012 in their paper, a foot print recognition was implemented using Principal Component Analysis algorithm. The objective was to implement a foot recognition system using Principal Component Analysis algorithm to identify given foot image from database and designed accordingly a training set. The methodology adopted includes the three main stages of foot print recognition system, which are image pre-processing, feature extraction and template matching. Footprint recognition in the research faces several challenges in areas such as identification and illumination changes.

Uhl and Wild, 2008 designed a Footprint-based biometric verification system, The objectives of the research include; examining the application of some of the hand biometric features in foot biometrics and is the introduction of a prototype footprint verification system. The research designed an image-based multimodal footprint verification system using input images with 256 grey levels of an HP 3500c flatbed scanning device as the single sensor operating at 600dpi resolution. In order to provide each of the different feature extractors with adapted image resolutions, bilinear down sampling is applied. The proposed foot-biometric authentication system consists of separate modules for pre-processing, including image registration and enhancement, feature extraction and matching.

Zhang and Nigel in their research work , automatic shoeprint retrieval system for use in Forensic Investigations (n.d), discussed that Shoeprints are often found at crime scenes and contribute considerably to forensic intelligence. Such as linking crime scenes, linking suspects in custody to other crime scenes. Permit the targeting of prolific offenders. Provide strong courtroom evidence when detailed matching of mark and shoe exist. This research was motivated because current solution is done manually, by searching through paper catalogues, the semi-automatic that follows involves human coding of outsoles pattern of shoeprints based on primitive shapes such as logos, curves, lines and zigzag patterns. These two approaches are tedious, slow and needs considerable training. Hence the need for an automatic system of shoe print identification

Adetunmbi and Osisanwo in 2013 considered the relevance of foot print in crime suspect identification, since it is natural for any criminal to walk into a crime scene. The proposed system unobtrusively gathers shoeprints from users who gain access into a room by installing an inkless footprint kit in an unnoticeable point at the entrance. Shoe prints which are retrieved at the close of each day's activity are secretly captured, these prints are gathered and worked upon by extracting the features from the shoe prints and the process of recognition followed by analyzing, comparing and evaluating all the likely characteristics of the out sole of the shoe from its prints. The characteristics of the shoe outsole present on the shoe prints are analysed such as the wear prints which are often caused by the weight bearing area, the size of the shoe, the width of the ball and heel, the wear area of the ball and heel of the feet based on the individual's weight were analysed from the print. Features are extracted from the shoe prints gathered, and the edges detected so as to pin point the wear area of the pattern on the shoe prints which are caused by the pressure exerted by the foot on the shoe. In this paper, the detection is implemented by using the

Canny Edge detector which at first smoothes the print for noise elimination, by using a 5x5 filter.

3. IMAGE PROCESSING TECHNIQUE

Image processing is a subset of the electronic domain or digital signal processing whereby an image is converted to an array of small integers, called pixels, representing a physical quantity such as scene radiance, stored in a digital memory, and processed by computer or other digital hardware (Silver, 2000). Image processing can be defined as a process of extracting meaningful and useful information from an image. (Elias et al, 2009). The image is divided into small regions called picture elements or pixels. The pixels are then analysed for information gathering. The procedures for image processing or analysis are discussed:

Image acquisition: the image to be processed is acquired through a digital device and compressed to an image file.

Pre-processing: the acquired image may be enhanced by improving contrast, sharpness, color and so on.

Segmentation: refers to the process of partitioning a digital image into multiple segments (sets of pixels) known as super-pixels. The goal of segmentation is to simplify and or change the representation of an image into something that is more meaningful and easier to analyse, they are used to locate objects and boundaries in images.

Presentation and description: in this step, each of the segmented area may be characterised by statistical data, for example principal component analysis, texture, aspect ratios of a segmented area, or the color.

Matching recognition and interpretation: this phase involves using characteristics derived in the previous step to match each individually segmented area based on specific recognition algorithms.

Knowledge base: finally, the feature vector above may be fed to a knowledge base of all known subjects Shih (2010).

4. FOOT PRINT RECOGNITION SYSTEM

Foot prints are treated as images for analysis, the foot print recognition system adopts image processing techniques for verification or identification processes.

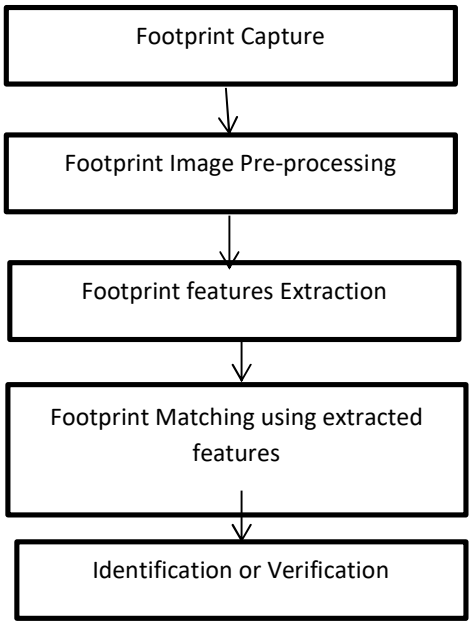


Figure1 Stages of footprint recognition Algorithm

Figure 1 shows the various stages of foot print recognition process.

5. THE PROPOSED SYSTEM

The proposed system adopts the footprint recognition system which is based on image processing techniques. This process involves three to four major stages or steps. The stages involved are discussed here. The architectural frame work for the proposed system

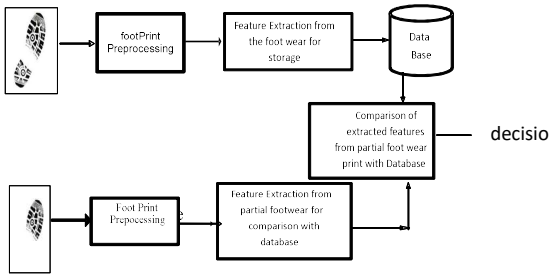


Figure 3.1 The Architecture of the proposed System for person identification

5.1 Footprint Acquisition

Image acquisition is the first step of the foot print recognition process. The acquisition was done manually. Ink pads were used to acquire the prints by requesting volunteers to step on ink pads and print on card boards. Up to 200 data set were gathered with no restrictions or boundary set. These prints were acquired by asking them to step on an ink pad with their right leg, while the left leg was on the floor, and then printing the corresponding print on a piece of white cardboard paper three times. The right leg data alone were considered.

5.2 Footprint Preprocessing

Step 1: **Noise Removal:** To de-noise the footprint one of the linear smoothing filters: Gaussian filter was introduced. The Gaussian filters smooth an image by calculating weighted averages in a filter box, it represents the shape of a Gaussian (bell-shaped) hump, will screen noise with the high spatial frequencies and produce a smoothing effect.

The 1D Gaussian filter function is

$$G(x) = \frac{1}{\sqrt{2\pi\sigma}}\, e^{-x^2/2\sigma^2} \quad (1)$$

The Gaussian filters function for 2 Dimensional images:

$$G(x,y) = \frac{1}{2\pi\sigma}\, e^{-(\frac{x^2+y^2}{2\sigma^2})} \quad (2)$$

where σ is the standard deviation of the Gaussian distribution, it is the scale parameter for noise removal

x is the distance from the origin of the image(foot print) in the horizontal axis,

y is the distance from the origin of the image(foot print) in the vertical axis

Further enhancement will have to be done to the images for clearer analysis

Step 2: **Segmentation:** The footprints are segmented into clusters in order to separate the weight or pressure bearing areas of the foot print. The K- means clustering algorithm was adopted for this process

$$v = \sum_{i=1}^{k} \sum_{x_j \in s_i} (x_j - \mu_i)^2 \quad (3)$$

where there are k clusters, i = 1, 2, 3,…, *k*

x_j is the vectored image (Foot prints)

j is from 1,2,3,…,n and n is the size of the vector

s_j is the cluster set in which x is grouped to

μ_i is the centroid intensities, that is the mean point of a point $x_j \in s_i$ $v = SSE$; Sum of Square Error

5.3 Footprint Feature Extraction

After the footprints have been enhanced and segmented, necessary features are extracted; on the footprints the features from the weight bearing regions were extracted. The algorithms or a technique employed is the Principal Component Analysis (PCA).

(a) ***Principal Component Analysis (PCA)***

PCA is a useful statistical technique that has found application in fields such as face recognition, pattern recognition, and image compression, and it is a common technique for finding patterns in data of high dimension.

Mathematically, PCA depends upon the eigen-decomposition of positive semi-definite matrices and upon the singular value decomposition (SVD) of rectangular matrices. When using these sorts of matrix techniques, image representation must be considered.

The steps involved are

Step 1: *Vectorize the footprint*

$X = (x_1, x_2, x_3 \ldots x_N^2)$ (4)

where *N* is the size of the vector.

Step 2: *Normalize the vector images*

The images are mean centred

$$m = \frac{1}{N}\sum_{i=1}^{N} X_i \quad (5)$$

where m = mean.

N = size of vector and X is the vector image

Step 3: matrix *A* of the mean centered vector is created

$$A = \{w_1, w_2, w_3 \ \ldots w_N\} \quad (6)$$

Step 4**:** Compute the Eigenvector v_i of the covariance matrix

$A^T.A$ is considered

Compute the Eigen vector e_i of the $A^T.A$ such that

$A^T.A\ e_i = u_i e_i$

$v_i = Ae_i$ ...7

The Eigenvalues are then given by the characteristic equation $det(A - \Lambda I_n) = 0$

The extracted features were stored in a database. To create a robust storage of foot prints. Then partial foot prints are equally gathered and made to go through same process before pattern matching is done or comparison is made with the content of the database

5.4 Footprints Pattern Matching/Footprints recognition

After the necessary features had been extracted a comparative analysis was carried out on the patterns of the features for matching to identify images (foot print) that are related. The extracted features of the partial foot print are compared with the extracted features of the foot print in database for relationship using the Euclidean Distance technique

In a 2-Dimensional image is given by

$$d(x,y) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2} \quad (7)$$

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \quad (8)$$

where x and y are the Euclidean vectors,

$d(x,y)$ *denotes the distance between vectors x and y*

x is the distance between the origin of an image and a pixel on x axis

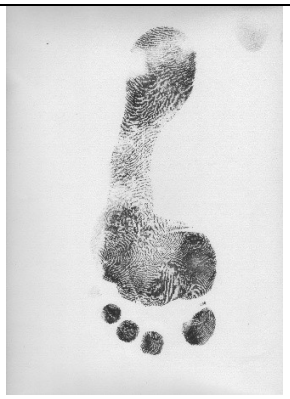
y is the distance between the origin of an image and a pixel on y axis

n is the number of variables

6. RESULTS AND DISCUSSION

Raw data acquired from volunteers were stored first in a folder after they have been scanned. On these images a little adjustment had to be done, the prints were ensured to have same orientation. Samples are shown in figure 3

volunteer 001



volunteer 002

volunteer 003

volunteer 004

Figure 3 samples of footprint stored in database

Table 1 the result table showing the test image (partial footprint) being tested against trained foot prints

TIME TAKEN: 14seconds

Gaussian value	Cluster value	Eigen value	Foot Print ID	Calculated Euclidean Distance
5	10	5.0	V001FOOT.jpg	38
5	10	5.0	V002FOOT.jpg	0
5	10	5.0	V003FOOT.jpg	0
5	10	5.0	V004FOOT.jpg	18
5	10	5.0	V005FOOT.jpg	0
5	10	5.0	V006FOOT.jpg	0
5	10	5.0	V007FOOT.jpg	0
5	10	5.0	V008FOOT.jpg	1
5	10	5.0	V009FOOT.jpg	5
5	10	5.0	V010FOOT.jpg	2
5	10	5.0	V011FOOT.jpg	11
5	10	5.0	V012FOOT.jpg	42
5	10	5.0	V013FOOT.jpg	0
5	10	5.0	V014FOOT.jpg	0
5	10	5.0	V015FOOT.jpg	0
5	10	5.0	V016FOOT.jpg	78
5	10	5.0	V017FOOT.jpg	75
5	10	5.0	V018FOOT.jpg	35
5	10	5.0	V019FOOT.jpg	0
5	10	5.0	V020FOOT.jpg	16
5	10	5.0	V021FOOT.jpg	0

footprint. The returned feature value confirms that the test footprint is related to or belongs to the trained foot print with the highest distance between them both. The footprint with ID V025 is same as the partial footprint tested.

7. PERFOMANCE EVALUATION OF THE SYSTEM

The efficacy of the system developed was determined by considering the following;

i. Time taken: the time taken for a test image to go through all the processes, before its features were matched against the entire feature vector kept in the feature database was equally measure.

ii. Standard performance metrics: For any biometric or classification system, the main performance indicator is the receiver operating characteristic (ROC) curve, which is a plot of True Acceptance Rate (TAR = 1-FRR, the False Rejection Rate) against False Acceptance Rate (FAR)

$$FAR = FP/(FP + TN)$$

FRR = FN/(FN + TP)
TAR = 1 – FRR
also
FAR = FA / TA

Accuracy ACC = (TP + TN) / POPwhere TP represents True Positive,

TN represents True negative,

FP represents False Positive

FN represents False Negative

FA = Number of False Acceptances
TA = Total Number of Attempts

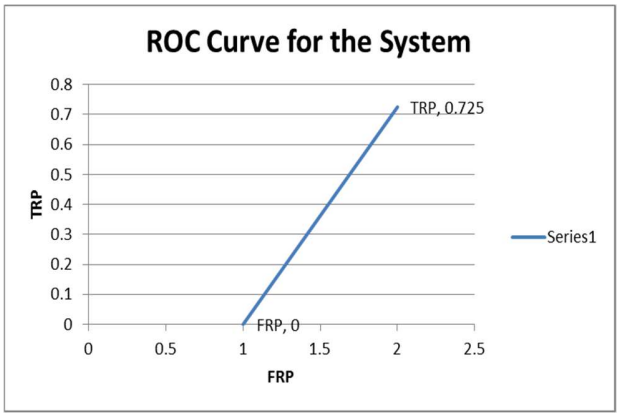


Figure 4 ROC curve of the System

So the ROC curve is interpreted to have perfect classification since there are no false negatives, hence it can be concluded that the system is efficient
Also, accuracy is calculated as

Accuracy ACC = (TP + TN) / POP = (145 + 0)/ 200

= 145/200

= 0.725

Accuracy is expected to be 1, with 0.725 which is 72.5% level of accuracy it can be concluded that the system is efficient with 72.5% accuracy.

POP represents total population (11)

ROC = TAR vs FAR (12)

(13)

Table 2 the confusion matrix table

TP=145	**FP=0**
FN=55	**TN=0**

FAR = FP/(FP + TN) 0/(0+0) = 0
FRR = FN/(FN + TP) 55/(55 + 145) 55/200 = 0.275
TAR = 1 – FRR 1 - 0.275 = 0.725
The best possible classification would yield a point on coordinate (0, 1) of the ROC curve.
This represents 100% sensitivity that is no false negatives and 100% specificity. This is called perfect classification.

8. CONCLUSION

Designing a person identification system with consideration for partial foot print, which could be the only evidence found at crime scene for tracing the criminal or the only body feature at accident scene that can identify a body. The research created a database for foot print and adopted the image processing technique for its analysis, then partial prints were taken from some of the footprints and compared with the footprints in the database. The efficiency of this designed system has 72.5% accuracy, hence it was concluded that the system is efficient and reliable.

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