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FINGERPRINT RECONSTRUCTION FROM CYLINDICAL OBJECTS USING IMAGE MOSAICING

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Abstract: Fingerprints are an intriguing part in forensics, criminology, and biometrics. The challenges evolve when the analysis has to be made from an irregular object for instance a cylindrical object. The chances of attaining a partial print is maximum. Moreover, in the present scenario, the fingerprint is obtained using tapes for registering them in a planar fashion. This process involves risk of damage to the fingerprint or not obtaining the total print. Therefore, the need for this research involves construction of fingerprints from cylindrical objects with a noncontact approach. In this research, the reconstruction of the fingerprint is done by taking images of the object from different angles and stitching them based on Random Sample Consensus (RANSAC) and Scale Invariant Feature Transform (SIFT) algorithm to obtain a rolled or a complete print. The obtained print is subdued with a registered print in database to identify the individual.

Keywords: Forensics, latent fingerprints, cylindrical object, image mosaicing.

1. INTRODUCTION

Forensic science is evolving at a very rapid pace in the present era. The need for new technology in detecting different features in forensics is eminent. One such important aspect of forensics is fingerprint detection. Fingerprint can be categorized into three types broadly: Rolled impression, Normal or plain impression and Latent impression. Rolled impression incorporates the maximum amount of information from one tip of the finger to the other whereas plain impressions are void with the distortion in rolled impression and involves only a certain area. Both these impressions can be attained at ease by scanning the region of interest. To obtain latent impressions, a more complex method dusting or chemical processing [1] is carried out as these prints are absurd in nature. Compromised quality of friction based impressions, minute finger contact area and excessive non-linear distortion are some of the main difficulties in latent fingerprint matching.

Latent fingerprints have been playing a very important part in conviction since centuries. Most of the time it is seen that the latent prints are partial in nature and cannot provide us the total information. There are many such cases in the world in which the conviction was not proven due to inability to get a complete print and there are also cases in which falsified conviction is made due to improper match of the prints. One of the most important cases in which such a blunder was done is the case of Brandon Mayfield who was wrongly apprehended in the Madrid train bombing incident after a latent fingerprint obtained from the bombing site was incorrectly matched with his fingerprint in the FBI database [2]. If several latent prints are obtained, a correlation can be made of it. In cylindrical objects, the impression is latent in nature and therefore if many impressions are collected from the object, it may help us to reconstruct the total fingerprint or a quantifiable part for conviction. This method can reduce the chances of false conviction at an extensive rate [3, 4]. Now a day, fingerprint acquisition is done touchless in nature or by using 3D live scan technique using stereovision with multiple cameras to facilitate the whole finger [5, 6, 7]. This technology can be used to evaluate fingerprints from cylindrical objects [8, 9].

Chulhan Lee et. al., have illustrated the need for noncontact an approach for fingerprint reconstruction and the issues of 3D to 2D image mapping for the reconstruction [10, 11, 12, 13]. Anil K. Jain et. al., inferred that singularity, ridge quality map and ridge flow map are the most effective features in improving the matching accuracy [1, 14, 15]. Matthew Brown et. al., have developed an algorithm to create mosaicing of images using multi band blending and gain compensation technique to remove the image distortion and the effect of variation in image contrast in consequent images to be mosaicked [16, 17]. Jos´e Hern´ andez-Palancar et. al., c has developed an algorithm for both latent and non-latent fingerprint impression identification to about 100% matching index as an accurate way for evaluating a match [18]. Nalini K. Ratha et. al., evaluated a method to construct a rolled fingerprint from an image sequence of partial fingerprints using a live-scan fingerprint imager [19].

The fingerprint obtained from a cylindrical object is itself partial in nature and therefore it is sometimes difficult to be traced. Moreover, special care must be taken for extraction of fingerprints from a cylindrical object as the surface of the cylinder is curvilinear in nature. This case can be illustrated as a plain impression on a rolled object. Therefore, the main objective of the work lies in reconstruction of the fingerprint in a rolled impression form from the fingerprints obtained from a cylindrical object.

Following organization is used in this paper. Section II describes the block diagram and method used. Next section III shows the results of algorithm used for fingerprint construction. Section IV explains the conclusion.

2. METHODOLOGY

Image mosaicing is a very intuitive approach to stich many images together for decades and hence, this methodology is used to evaluate the authenticity of latent prints over a cylindrical object. Figure 1 shows the block diagram of the methodology used for image mosaicking of cylindrical finger print.

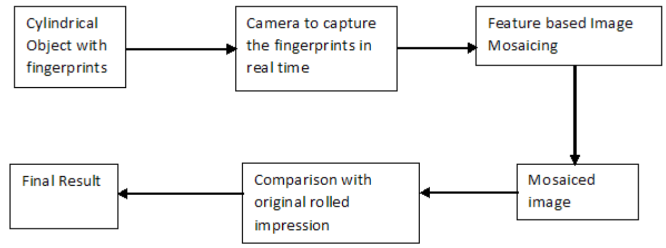

Figure 1: Block diagram of the methodology used for image mosaicking of cylindrical finger print.

The first step in construction of fingerprint is accumulation of the images from the cylindrical object. A total of 7 images were captured with a span of 15 degrees in both sides taking apex at 0 degree. The Table 1 shows the samples of cylindrical finger print images.

Table 1
Cylindrical finger print data set with angle orientation in term of degree

Angle (In Degree)	*Image Name*	*Sample Space*
–45	1	5
–30	2	5
–15	3	5
0	4	5
15	5	5
30	6	5
45	7	5

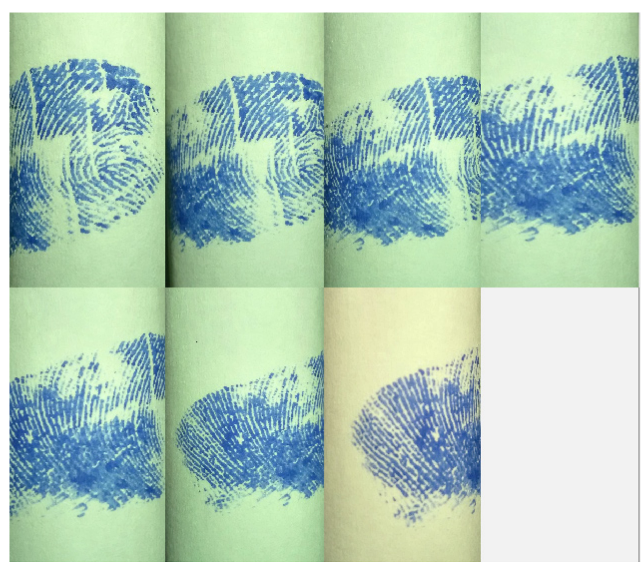

Figure 2: Cylindrical Finger print data set

A. Feature Matching

The second step involves the matching of the features of the images based on Scale-invariant feature transform (SIFT) algorithm. SIFT (Low 04) features were extracted and matched for the images. SIFT features are obtained by using maxima/minima of scale-face into a difference of Gaussian function. This is used to calculate a characteristics scale and create orientation of features which can measure the similarity-invariant frame [16]. The invariant descriptor is calculated by estimating the local gradient in the orientation histogram.

SIFT features do not vary with rotation and scaling therefore orientation and zooming of image can be handle by system. Thus, if the camera is rotating about the optical center, the transformations that the images will prevail are a special group of homographies. Let us parametrize the camera by a rotation vector $\boldsymbol{\theta}$ and focal length f. Thus, the pair wise homographies is given by,

$$\tilde{v}_i = P_{ij}\tilde{v}_j$$

where, $$P_{ij} = T_i R_i R_j^T R_j^{-1} \tag{1}$$

and $\tilde{v}_i$, $\tilde{v}_j$ are the homogeneous image positions.

The camera model's four parameters are defined by:

$$T_i = \begin{pmatrix} f_i & 0 & 0 \\ 0 & f_i & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{2}$$

and

$$R_i = \begin{pmatrix} 0 & -\theta_{i3} & \theta_{i2} \\ \theta_{i3} & 0 & -\theta_{i1} \\ -\theta_{i2} & \theta_{i1} & 0 \end{pmatrix} \tag{3}$$

Moreover, for minute changes in image position,

$$v_i = v_{i0} + \left.\frac{\partial v_i}{\partial v_j}\right|_{v_{i0}} \Delta v_j \tag{4}$$

or $$\tilde{v}_i = Q_{ij}\tilde{v}_j$$

where, $$Q_{ij} = \begin{pmatrix} q_{11} & q_{12} & q_{13} \\ q_{21} & q_{22} & q_{23} \\ 0 & 0 & 1 \end{pmatrix} \tag{5}$$

Q_{ij} is the affine transformation induced from linearizing the holography about $\tilde{v}_i$. This implicates small patches in the image undergoes affine transformations and thus, the justification of SIFT feature in this case is done.

B. Image Matching

This stage involves the matching of the common features of the images or the overlapping features between images. Firstly, RANSAC is used on the set of images (M = 7) to calculate a set of inliers that can be compared with image homographies. A probabilistic model is used then to implicate the match. RANSAC calculates the parameters of mathematical model from a series of observations. By iterative selection of a random subset of the original data goal will achieves [17].

This technique is used to compute the matching features and form a probabilistic model for image matching. This model is evaluated for 5 sets of samples for construction of the panorama based reconstructed fingerprint.

C. Final Image Size Computation

After the features are matched and the image matching/stitching is done, the outer limits for the transformation is calculated using affine transformation as shown in the equation 6. Bundle adjustment is made based on robustified sum squared projection error which is given by

$$E = \sum_{i=1}^{M} \sum_{j \in I(i)} \sum_{k \in F(i,j)} h(r_{ij}^k) \tag{6}$$

where, M is the number of images

I(i) is the collection of images matching to image i.

F(i, j) is the collection of matched features between images i and j.

As the error is computed, the final size of the panorama is calculated using automatic panorama straightening algorithm [16]. Once the panorama is formed, the final image is subjected to gain compensation and multi band blending. Figure 3 shows the stitching of the images based on only feature matching and image stitching.

D. Panorama Straightening

As the number of images increases more than 5, the transformation matrix evaluated in the previous steps creates a rotational distortion (or wavy distortion) in the mosaicked image. This distortion is basically due to the rotational pane of the image capturing device or the periphery of the cylinder.

In this step, the wavy variation seen in the Figure 3 is eliminated. This wavy output can be corrected by heuristic about the way people typically shoot panoramic images. The idea is that it is comparatively rare for people to twist themselves along with the camera horizon, therefore the camera's horizontal axis lies in a plane [16]. The up vector can be calculated from the covariance matrix of the X vector of the camera using the equation 7. This equation gives us the similarity transformation to be carried to remove the wavy nature of the output image.

$$\left(\sum_{i=1}^{N} X_i X_i^T\right) v = 0 \tag{7}$$

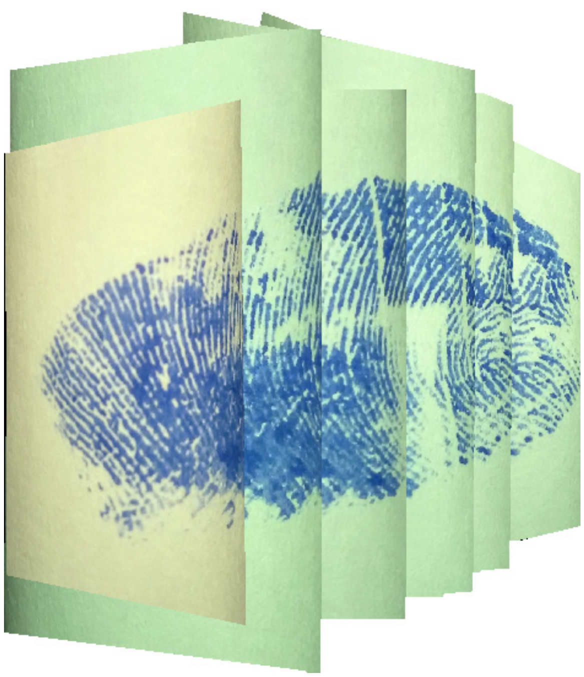

Figure 3: Stitched panorama of the fingerprint.

E. Gain Compensation

This method helps us in computing and eliminating the overall gain between the images and hence enhances the photometric quality of the final image. The error function is given by the sum of gain normalized intensity errors [6, 17].

$$E = \frac{1}{2}\sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{\substack{v_i \in R(i,j) \\ \tilde{v}_i = P_{ij}\tilde{v}_j}} (k_i I_i(v_i) - k_j I_j(v_j))^2 \tag{8}$$

where, k_i, k_i are the gains,

$R(i, j)$ is the common region between images i and j.

$I_i(u_i)$ is approximated with the mean of the overlapping region given by [5, 14].

$$\bar{I}_{ij} = \frac{\sum_{v_i \in R(i,j)} I_i(v_i)}{\sum_{v_i \in R(i,j)} 1} \tag{9}$$

By using the optimal solution at $k = 0$, the equation 9 can be modified as

$$E = \frac{1}{2}\sum_{i=1}^{M}\sum_{j=1}^{M} N_{ij}((k_i \bar{I}_{ij} - k_j \bar{I}_{ji})^2 / \sigma_N^2 + (1 - k_i)^2 / \sigma_g^2 \tag{10}$$

F. Multi Band Blending

To obtain information from different images, a weight function is attached to image $I(x, y) = i(x)i(y)$, where $i(x)$ varies linearly from 1 to 0 at center to the edge of the image respectively.

The equation used for multi band blending is as follows [8, 9, 15].

$$I^{lin}(\theta, \phi) = \frac{\sum_{i=1}^{N} I^i(\theta, \phi) Q^i(\theta, \phi)}{\sum_{i=1}^{N} Q^i(\theta, \phi)} \tag{11}$$

where, $I^{lin}(\theta, \phi)$ is a composite spherical image formed using linear blending.

3. RESULTS

The matching of the images is carried out with the concept of Pearson's coefficient. This coefficient evaluates the correlation between the images in a scale

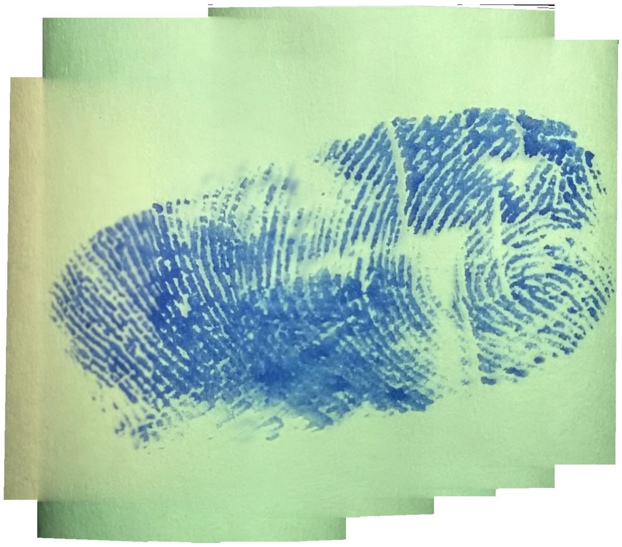

Figure 4: Final image with automatic panorama straightening, gain compensation technique and multi band blending.

of [−1, 1] whereas −1 implicates negative correlation,0 implicates no correlation and 1 represents positive correlation. The equation for evaluating the two images are as follows.

The Table 2 shows the genuine score and imposter score for the sample space of 5 samples.

Table 2
Matching statistics

Sample Set No	*Genuine Score*	*Imposter Score*
1	0.8351	0.4123
2	0.7612	0.3219
3	0.8011	0.2137
4	0.7834	0.2425
5	0.8120	0.3821

As the above correlation is based on Pearson's coefficient and the results implicates an average matching index of 80% approximately which is high enough to get a correct conviction. The average value of false matching or imposter matching index is below 50% and therefore can be discarded.

Figure 5 shows the Percentage score for genuine and imposter based on Table 2.

4. CONCLUSION

It is observed that the fingerprint mosaicing approach is suitable for conviction and can be used as a tool

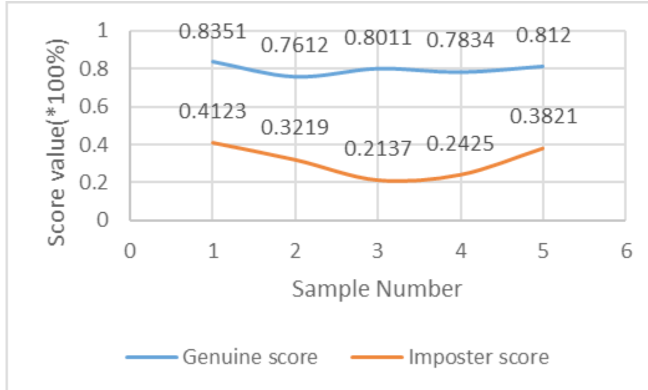

Figure 5: Percentage score for genuine and imposter based on Table 2.

for attaining complete print and matching it with the convicted person. The accuracy of matching index is about 80-85% and is high enough for conviction. Furthermore, the detection accuracy of fingerprints also varies on the span of the image taken. The accuracy of matching decreases as the span is increased. A gradual inclination in the imposter score is seen due to the variation of miniaturized details in the samples of fingerprints from different users and can be discarded for conviction.

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