Swarm Intelligence based Cuckoo Search Algorithm for Latent Fingerprint Recognition

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ABSTRACT Swarm Intelligence is a branch of artificial intelligence concepts that are inspired from the outstanding properties of natural social species like ants, bees, birds, fishes etc. There are various applications of swarm intelligence concepts in the fields of technology, medical, remote sensing, and optimization of various NP hard problems. Swarm Intelligence based concepts are particle swarm optimization, firefly algorithm, ant colony optimization, bat algorithm, bee colony optimization algorithm, and cuckoo search etc. Here, cuckoo search based concept is used for the latent fingerprint recognition. The reason for the selection of cuckoo search over other algorithms is the clever behavior and brood parasitic property of cuckoo bird to store their egg in other bird's nest. Latent fingerprint are the partial fingerprints captured during the crime scene that accidently left by criminals. In this research paper, an autonomous system based on cuckoo search is proposed to identify these criminals based on the latent fingerprints. This proposed system is validated based on the NIST SD-27 with the evaluation of results in terms of identification rate. The evaluated results indicate the superiority of proposed system as compared to other considered latent fingerprint recognition concepts.

Keywords-*Swarm Intelligence; Cuckoo Search; Latent Fingerprints; Fingerprint Recognition; Crime Scene; Biometric Systems*

1. INTRODUCTION

Biometric systems are the scientific automation systems to recognize the identity of the person. There are various means of biometric system like fingerprint matching, eye iris matching, face recognition, etc [1]. Here, major focus is presented on the fingerprint based human identity recognition. There are three types of fingerprints as mentioned plain fingerprints, latent fingerprints and rolled fingerprints [2]. Plain fingerprint is complete fingerprint of the suspect but it is obtained without rolling the finger. Rolled fingerprint is also the complete fingerprint of particular suspect obtained under controlled or supervised conditions. The finger is rolled "nail to nail" on a paper or scanner to get the print. Latent fingerprint, perhaps found at crime scenes, is the partial fingerprint which is left inadvertently by the suspect on any surface. It is sometimes called as trace, mark, or finger-mark.

Latent fingerprints are the finger skin impressions in a groove and ridge pattern left when fingertips come in contact with any surface [3]. In forensics investigation, latent fingerprints plays as principal evidence to identify and convict criminals. Due to the presence of overlapping noisy patterns and complex ridge structure, they are usually unclear and of poor quality. The discipline of latent fingerprint detection has gain attention of many researchers over the years and many advances have been made but it is still challenging to accomplish the task by offering a quick, reliable and accurate latent fingerprint detection system. The presence of spoiled minutiae information, ridge and overlapping patterns make the task more complicated. The latent fingerprints do not serve any purpose before pre-processing steps of the ridge patterns, minutiae information and their quality. Prior to latent fingerprint detection and feature extraction, latent fingerprint enhancement is absolutely requisite to improve the quality for accurate fingerprint detection. After the steps of fingerprint pre-processing, enhancement, and feature extraction, there is the step of final fingerprint matching which is based on the minutiae matching step. Here, swarm intelligence based cuckoo search is applied for the final recognition of latent fingerprint. The proposed concept is named as CSLFR (Cuckoo Search based Latent Fingerprint Recognition)

Swarm Intelligence is an artificial concept inspired from the collaborative multi-agent social species that work intellectually to design intelligent system and optimized algorithm. Based on the variety of social species of insects and animals, there exists a number of Swarm Intelligence techniques. Some of the popular swarm intelligence techniques are listed as: Bat Algorithm, Ant Colony Optimization, Cuckoo Search, Firefly Algorithm, Intelligent Water Drops Algorithm, Biogeography Based Optimization, Particle Swarm Optimization, and Artificial Bee Colony Optimization. In this research paper, cuckoo search algorithm is used for the latent fingerprint recognition due to cleaver behavior and brood parasitic property of cuckoo bird to store their egg in other bird's nest.

Experimentation is performed on the dataset of NIST SD-27 for the performance evaluation. NIST SD-27 dataset consists of total 258 images which are subcategorized into 88 good fingerprint images, 85 bad fingerprint images, and 85 ugly fingerprint images. Results of the proposed system are

evaluated in terms of identification rate with comparison to other existing latent fingerprint recognition concepts.

The organization of rest of the paper is as follows: Section 2 presents the existing work related to latent fingerprint recognition. Section 3 discusses the proposed latent fingerprint recognition system based on cuckoo search approach. Section 4 presents the results and discussion along with the used dataset of NIST SD-27. Section 5 concludes the paper with future directions.

2. RELATED WORK

Different authors have used different algorithms and concepts for the latent fingerprint recognition. The consideration of dataset for the experimentation is also different as per the availability and adaptability by different authors. Some of the authors have used dataset related to small fingerprints, some used large dataset, and other have tested the proposed systems with real time fingerprints in which dataset can be very from smaller to larger. Paulino et al. [4] developed fingerprint matching algorithm especially for latent fingerprints based on Hough transform. The algorithm is designed for its application in law enforcement agencies. Matching experimental results on NIST SD27 and WVU latent database reveals the viability of proposed algorithm. Peralta et al. [5] proposed a framework to test the large database of fingerprints with more accuracy and swift matching. The authors have introduced a high performance distributed hardware framework to increase its response time in case of large databases. In additions, the proposed approach is also examined with NIST DB4 and NIST DB14 datasets for its aptness with rolled fingerprints. The experimental results clearly signified the importance of distributed approach over sequential approach in case of fingerprint matching with large databases. Medina-pérez et al. [6] proposed a technique to handle non-linear deformations in latent fingerprint images for robust latent fingerprint matching. The algorithm begins with the employment of local matching to handle translation, rotation and other minor deformations. The rank-I identification rate of the proposed method is higher in comparison to the state-of-the-art matching algorithms. Kumar and Velusamy [7] designed an algorithm to measure similarity score in case of latent fingerprint images. A bottom-up approach is employed to design a kernel based similarity score computational algorithm. The algorithm has potential to handle invariance due to rotation and scaling in latent fingerprint images.

More recently, Murugan and Rose [8] divulged the importance of minutiae extraction and matching for fingerprint identification. An artificial neural network is trained using back propagation learning approach with an objective to ameliorate feature for fingerprint matching. Three different matching experiments are conducted using three different fingerprint image filters namely Gabor filter, Median filter and Anisotropic filter. The matching results favoured Gabor filter with minimum equal error rate of 3.18%. Another similar concept based on minutiae is 4-D feature vector that was introduced by Ahmed and Sarma [9]. Experiments using four different databases (FCV 2000. FVC 2002, FVC 2004 AND NIST SD4) are conducted to analyse performance of proposed approach in terms of False Acceptance Rate, False Rejection Rate and Equal Error Rate.

3. PROPOSED CONCEPT (CSLFR)

The proposed system of CSLFR (Cuckoo Search based Latent Fingerprint Recognition) is based on the cuckoo search algorithm to recognize the latent fingerprints. The workflow of this proposed system is also presented in figure 1. The algorithm steps involved for the recognition of latent fingerprints are discussed here:

Input: Latent Fingerprint from NIST SD-27 dataset

Output: Matched Fingerprint Image

Algorithm

Step 1: The initial step of latent fingerprint recognition is the capturing the latent fingerprints from crime scene. Here, we have considered these fingerprints from NIST SD-27 which is a latent fingerprint database.

Step 2: Perform the segmentation process on the considered latent image to separate the useful latent fingerprint information from background and other noised structure.

Step 3: Enhance the latent fingerprints using Gaussian filter to reduce the noise value form the image.

Step 4: Binarise the grey level image to identify the minutiae information of latent fingerprint more clearly.

Step 5: Perform the step of feature extraction to extract the available minutiae points in the image. To identify the information of ridge bifurcation, ridge ending points, and normal pixel value, the entire is divided into 3*3 pixel windows. Based on the pixel window rules, these minutiae details are captured.

Step 6: These extracted minutiae can capture some false minutiae information. So, after the step of feature extraction, there is need to remove false minutiae information.

Step 7: Match the latent minutiae features with the original image using the concept of cuckoo search algorithm.

7.1: Assume the image pixels of latent image as the cuckoo egg and pixels of complete original image as the host nest.

7.2: Match the feature values of both the latent fingerprint image and original fingerprint image.

7.3: If the features of cuckoo egg (latent fingerprint) matched with the host nest (original image), then pixel will be consider as the match.

7.4: Repeat the step of matching for all the pixels and find the maximum matched image.

Step 8: Obtain the final matched image having maximum pixel match with the latent image.

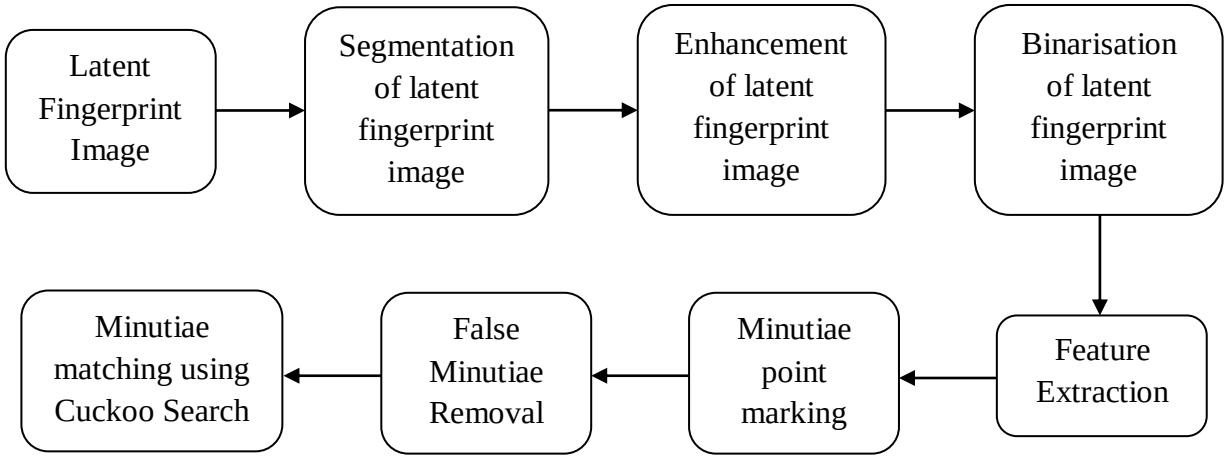

Figure 1: Workflow of Proposed CSLFR System

4. RESULTS AND DISCUSSION

This section presents the evaluated results based on the identification rate along with the considered NIST dataset. The proposed system is implemented using MATLAB version 8.3.0.532 and system configuration of Processor- Intel(R) Core(TM) i5@ 3.20 GHz, RAM- 4.00 GB and System type- 64-bit.

4.1. NIST SD-27 Dataset

The NIST SD-27 is a greyscale fingerprint special database composed by National Institute of Standard and Technology united with Federal Bureau of Investigation [10]. The dataset is a collection of total number of 258 latent cases collected from crime scenes along with matching fingerprint mates. These 258 images are subcategorized into 88 good fingerprint images, 85 bad fingerprint images, and 85 ugly fingerprint images. Some of the sample images from NIST SD-27 dataset are shown in figure 2. NIST SD-27 is a publically available dataset which is commonly used to develop and examine fingerprint detection systems.

(a) (b) (c)

Figure 2: NIST SD-27 dataset images (a) Good, (b) Bad, (c) Ugly

4.2. Experimentation and Comparison

The results of the latent fingerprint recognition system are evaluated based on the evaluation parameter of identification rate. The identification rate of the system is the ratio of number of identified matches to the total number of images as presented in equation (I).

$$Identification\ rate = \frac{number\ of\ identified\ matches}{total\ number\ of\ images}$$

Equation (I)

The quality of the fingerprint image directly influences by the identification rate. Separate experiments are performed for the Good quality latent fingerprint images followed by Bad and Ugly latent fingerprint images. The overall identification rate achieved by Good, Bad and Ugly quality fingerprint image is 97.72%, 87.05% and 83.52% respectively. This means that out of 88 Good quality latent fingerprint images 86 image are correctly identified. An identification rate of 87.05% and 83.52% corresponding to Bad and Ugly quality latent fingerprint images indicate that out of 85 images 74 and 71 images are correctly identified respectively. The performance of the proposed system is further evaluated by

comparing the results proposed by Ahmed et al. [11]. The author has presented the comparative results of several state-of-the-art techniques in terms of identification rate. Table 1 presents the comparative results of proposed system with state-of-the-art techniques.

Table1: Comparative results of proposed system with state-of-the-art techniques

Techniques	Identification Rate (in %)		
	Good	**Bad**	**Ugly**
Proposed System (CSLFR)	97.72	87.05	83.52
Embedded self learning segmentation [12]	71.6	63.83	60.89
Minutiae generated orientation fields [13]	95	80	60
Automated Clarity and Quality Assessment of Latent fingerprints [14]	67	NA	NA
Bozorth3 Algorithm [15]	85	97	92
Extended Feature set [16]	73	67	NA
Descriptor based Hough Transform [17]	81.4	67	39
Lights Out fingerprint Identification system [18]	78.82	67.04	27.05
Matching Latent fingerprint with rolled fingerprint [19]	93.4	NA	NA
Level 3 features[20]	69	63	NA

5. CONCLUSIONS

In forensics investigation, latent fingerprints plays as principal evidence to identify and convict criminals. As discussed in this paper, we have proposed CSLFR approach for the recognition of latent fingerprints. In this system, cuckoo search approach is considered due to clever behavior and brood parasitic property of cuckoo bird. Dataset of NIST SD-27 is used for the fingerprint recognition. Results are evaluated in terms of identification rate in comparison with existing concepts. Identification rate for the three different categories of Good, Bad, and Ugly are evaluated and compared. From evaluated results, it can be declared that proposed CSLFR system is efficient enough to recognize the latent fingerprints.

For future directions, the proposed CSLFR system can be tested on other available datasets such as IIIT-D Latent Fingerprint, IIIT-D SLF, and Latent Fingerprint Overlapped Database etc. Moreover, the proposed concept can be further improved by integrating the system with some soft computing technique.

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