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FEATURES EXTRACTION OF FINGERPRINTS BASED BAT ALGORITHMS

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Abstract- The majority of conventional techniques rely on clear-cut relationships. The smart card and password procedures are two of the most illustrative instances of them. Verifying that people are who they say they are is one of a security system's main duties. This paper presented a novel method for extracting Bat Algorithm-based features from fingerprint photographs (BA). The echolocation behavior of bats for distance perception served as the basis for the bat algorithm. Bats hunt at night by emitting brief, intense sound pulses and listening for the echoes that are reflected back from obstacles or prey. A bat's unique hearing system can assist it in estimating an object's size and location. Within the Features Extraction phase, the bat algorithm is applied as a pre-enhancing step that will choose the clear minutiae structures which will be more fit for the matching phase. The results show that the suggested system operates better when the BA algorithm extracts the best features for all user fingerprints in the database with the appropriate amount of time for each user.

Keywords: Fingerprint Features Extraction, Banalization, Swarm Intelligence, BA.

1. INTRODUCTION

We can recognize a humans based on a variety of features, which may include differences in overall look or some indication of age. A person's identity can be guessed or determined simply on the contour of his face or by hearing his voice. The authentication or identity verification process in computer systems is mostly based on traditional ways such as passwords or PINs, which can also refer to chip cards, magnetic cards, and keys [1]. Cards or keys, on the other hand, are frequently misplaced or stolen, and passwords are frequently forgotten or disclosed. We need to employ something that actually determines the person for more trustworthy identification or verification [2]. Biometric systems work by analyzing physiological and behavioral biometric data to determine a person's identity.

Signatures, speech, keystrokes, and gait are behavioral biometric factors that vary with age and circumstance. On the other hand, physiological characteristics like as the face, iris, palm print, and fingerprint do not alter during a person's lifetime [3]. Most biometrics systems operate in either identification mode or verification mode.

The requirements of the application decide the mode selection largely. By comparing gathered biometric data with a templated form, person ID validation is done in the verification mode. Identification mode identifies a user by applying fingerprint biometric template matches between the user's fingerprints. Because of their use, uniqueness, durability, dependability, accuracy, and acceptability, fingerprints have been utilized in everyday life for over a century. Each fingerprint is made up of furrows, ridges, and minutiae that are extracted using either ink impressions on paper or sensors. A high-quality fingerprint takes anywhere from 25 to 80 minutes to create, depending on the sensor's accuracy and the position of the finger on the sensor. False minutiae caused by inconsistent ink quantities, where false ridge fractures emerge in a state of insufficient ink or cross-connections appear in a state of excess ink. Poor-quality fingerprints, such as those with scars and scratches, injuries, or very dry fingertips, make it impossible to properly extract detail. Thinning, extraction, matching, and computing the score of minutiae matching are common procedures in fingerprint recognition based on minutiae [4].

Metaheuristics algorithms, particularly Swarm intelligence (SI) algorithms, are a key aspect of artificial intelligence (AI). The core concept of SI is inspired from natural life systems such as bird flocking, ant colonies, and mammal herding. The majority of SI algorithms have proven their usefulness in a variety of applications and computationally intelligent systems [5][6]. The Bat Technique, a metaheuristic algorithm for feature extraction, is employed in this paper (BA). A recently created heuristic optimization technique called BA uses bat echolocation as its basis. The bat approach, on the other hand, is vulnerable to local optima and, because of its limited global exploration capability, its optimization findings are unreliable.

2. LITERATURE SURVEY

This section displays background of techniques and approaches that could be related directly to the proposed technique consisting of detection and extraction.

In [7], Harith, Al-Sahaf, et al. a genetic algorithm was created to build an image descriptor to extract features from texture images using the LBP technique. They also use GP to reduce the maximum number of feature instances in selected datasets before comparing them to seven other datasets.

In [2], Al-Ta'l, et al. suggested the Firefly Algorithm as a technique for removing characteristics (extracting features) from an image (FA). This algorithm simulates the flashing behavior of fireflies in the wild. The results imply that the suggested algorithm is one of the best search techniques.

G. Sambasiva Rao, et al. [8] suggested a fingerprint recognition technique based on the grey-level watershed approach to detect rigidity.

In [9], M.R. Girgisa, et al., suggested a combination strategy that uses a genetic algorithm in one stage and a local search in another to define fingerprint matching that relies on both line extraction and graph matching concepts.

In [10], Mohamed, et al, proposed using a fuzzy neural network to create a fingerprint categorization system. They extract information such as singular points, core direction and locations, and delta after binarizing the fingerprint image. The proposed system achieves satisfactory categorization results.

In [11], Xifeng Tong, et al., the Local Relative Error Descriptor (LRLED) technique was suggested as a method for removing nonlinear distortion. This approach has three steps: (1) utilize a pairwise alignment to align fingerprints; (2) generate a set of matched minutiae with a threshold to limit non-matches; and (3) quantify similarity using the LRLED. LRLED excels at discriminating between m and n.

In [12], L. Lam, et al, offered a method for reducing the thickness of each pattern line to just a single pixel width. (1) The obtained thinner fingerprint picture must be one pixel wide without separators, according to the algorithm requirements for a fingerprint (2) every ridge must be narrowed (smoothed) to the center pixel (3) noise and single-pixel must be excluded (4) Once the thinning procedure is complete, pixels cannot be removed again.

3. PRELIMINARY

3.1. Database

Throughout the tests, the database FVC2002 (Fingerprint Verification Competition) is used. The database (FVC) is made up of several databases (DB1, DB2, DB3, and DB4) that collect data using the following technologies or sensors [13]:

- DB1: "TouchView II" Optical Sensor by Identix
- DB2: "FX2000" Optical Sensor by Biometrika
- DB3: "100 SC" Capacitive sensor by Precise Biometrics
- DB4: Fingerprint Synthetic Generator

The databases are 110 fingers wide (w) with 8 printers for each finger deep (d), resulting in a total dataset size of 880 fingerprints as indicated in Table 1. The dataset is then constructed with fingers numbered from 1 to 100 (Group A) [14]. Group (B) begins with fingers numbered 101 to 110, allowing participants to specify parameters before sending algorithms.

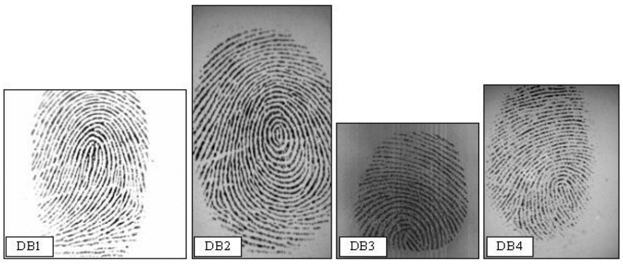

Figure 1. Images Sample with Different Image Sizes Taken from DB1, DB2, DB3 and DB4 [14]

3.2. Bat Algorithm

A recently created heuristic optimization method based on bat echolocation is called the bat algorithm (BA). Four fundamental factors make up the conventional BA: a constant, a velocity, a pulse frequency, and a pulse rate. The conventional BA has a slow convergence rate because it is challenging to balance global and local search.

In order to improve global search mobility and achieve robust global optimization, Gandomi and Yang [15] included chaos into the conventional BA (CBA). Alternative chaotic systems are employed in CBA in place of the parameters of BA.

Xie, et al. [16] suggested an enhanced BA due to the Lévy flight trajectory. Using the adaptively modified frequency technique, this algorithm can successfully exit local optima.

Gan, et al. [17] suggested a new BA based on stochastic inertia weight and iterative local search. The velocity updating equation includes a stochastic inertial weight that can improve the bat population's diversity and adaptation.

The distance-sensing echolocation behavior of bats served as inspiration for the BA. Bats hunt at night by emitting brief, intense sound pulses and listening for the echoes that are reflected back from obstacles or prey. A bat's distinct hearing system can help it determine the size and position of an object. On the basis of this bat echolocation trait, Yang [18] designed the BA. The following is a summary of the actions that BA took:

- Step 1: Describe the parameters for bat, as shown in Table 1.
- Step 2: Update the global best position X^*, pulse frequency, velocity, and position of the *i*th bat as follows [16]:

$$f_i = f_{\min} + (f_{\max} - f_{\min})\beta,\ \beta \in [0,1] \quad (1)$$

$$V_i^{t+1} = V_i^t + \left(X_i^t + X^*\right) f_i \quad (2)$$

$$X_t^{t+1} = X_i^t + V_i^t \quad (3)$$

Table 1. The bat parameters [16]

M	The size of bat population
N	Max number of iterations
I	The number of bats, in range [I, M]
X^*	The current global best location (solution)
X_i	The position of ith bat
V_i	The velocity of ith bat
f_i	The pulse frequency of the ith bat and its range is between $f_{\min}$ and $f_{\max}$
$f(X)$	Fitness function
r_i	The pulse rate of ith bat
A_i	The loudness of ith bat
α	The constant parameter in range [0,1] used to update the pulse rate A_i
γ	The constant parameter in range [0,1] used to update the pulse rate r_i

A random number between 0 and 1, where, V_i^t and X_i^t are the velocity and position at time t+1, and V_i^t and X_i^t are the velocity and position at time.

- Step 3: In the event that the irregular number is greater than r_i, utilize the accompanying condition to make another answer for the bat.

$$X_{new} = X_{old} + \varepsilon A^t \tag{4}$$

where, is $\varepsilon\epsilon$(-1,1), The average volume of all bats at time t is represented by the A^t random number.

- Step 4: The new solution is allowed if the random number is less than A_i and $f(X_i)<f(X^*)$. Next, make the updates to A_i and r_i, respectively, as follows [16] :

$$A_i^{t+1} = aA_i^t \tag{5}$$

$$r_i^t = r_i^0 \left[1 - e^{-\gamma t}\right] \tag{6}$$

The hybrid algorithm's population is separated into numerous subpopulations in a parallel structure, each of which is updated in uniform iterations. The exchange of information across populations begins when the communication strategy is enabled. As a result of this procedure, the benefit of combining the individual strengths of both types of algorithms is realized. However, in order to gain from cooperation, a method of replacing weaker persons while performing algorithms and other tasks should be implemented [16].

In Equations (5) and (6), the A_i^{t+1} and A_i^t indicate the occasionally loudness t and $t+1$, respectively; r_i^0 and r_i^t are the initial pulse rate and pulse rate at time t, respectively, α is a constant variable within [0, 1], γ>0. As t lead to ∞, A_i^t led to 0 and r_i^t lead to r_i^0.

- Step 5: Determine the current best option X^* by classifying the bats according to their fitness.
- Step 6: Once the maximum number of iterations has been achieved, go back to Step 2 and output the globally optimal solution.

4. APPLICATIONS AND CASE STUDY OF BAT ALGORITHM

Since the original bat algorithm (BA) has been developed by Yang in 2010 [19], bat algorithms and its modifications have been applied in almost every area of optimization, image processing, feature selection, scheduling, classifications, data mining and others.

4.1. Image Processing

In 2012, Du, et al. introduced a modified version of the bat algorithm with mutation for image matching, and they claimed that their bat-based model is more practical and effective at matching images than models like genetic algorithms and divergent evolution.

4.2. Inverse Problems and Parameter Estimation

A chaotic Levy flight bat algorithm was published by Lin et al. (2012) to estimate parameters in nonlinear dynamic biological systems, demonstrating the efficacy of the suggested algorithm.

4.3. Fuzzy Logic and Other Applications

For exergy modeling, Lemma et al. (2011) used fuzzy systems and the bat algorithm. Tamiru and Hashim (2013) employed bat algorithm to explore fuzzy systems and to model exergy fluctuations in a gas turbine.

4.4. Continuous Optimization

Numerous studies have been conducted on continuous optimization in relation to engineering design optimization. Highly nonlinear issues can be effectively handled and precisely solved with BA. Bora, et al. (2012) improved the brushless DC wheel motors using the bat algorithm with better results. Table 1 will highlight some of the applications of BA [20].

Table 2. BA applied area [21]

Area/Applications	Author
Classification, wireless sensor, data mining	Yang, et al, [22]
Design of a conventional power system stabilizer	Sambariya and Prasad [22]
Fuel arrangement optimization of reactor core	Kashi, et al. [23]
Feature selection	Taha, et al. [24]
Economic dispatch	Latif and Palensky [25]

5. PROPOSED SYSTEM

We present in this section, the details of the steps of the practical part of the proposed system are explained.

5.1. Input Fingerprint Image

Each fingerprint input image must be in grayscale mode, with intensity values ranging from 0 to 255. The ridges and valleys in a fingerprint impression make up the image. Normally, ridges appear as dark lines, whereas valleys are the light spaces between the ridges. When the ridge becomes interrupted, the tiny points appear. Ridge termination or bifurcation is when a ridge comes to an end or divides into two ridges. The minutiae have two types of bifurcations and terminations that are more crucial than other features for a fingerprint image's further processing.

5.2. Fingerprint Enhancement

The fingerprint image is enhanced using the Fast Fourier Transform (FFT) analysis at this stage. The quality of the input pictures for a fingerprint's features extraction function and matching algorithm heavily influences how well they operate. Although a fingerprint's quality cannot be judged objectively, it is connected to how clearly the ridge is structured in the image, so it is important to enhance the image. While a "poor" fingerprint has low contrast and a blurry ridge border, an "excellent" fingerprint has strong contrast and sharply defined valleys and ridges. A fingerprint image's quality can be harmed for a variety of reasons. (1) The presence of wrinkles, cuts, or bruises can generate ridge discontinuities. (2) Excessively dry fingertips result in fractured and low-contrast ridges. (3) Fingerprint sweat causes smeared marks and the connection of parallel ridges.

5.3. Binarization

Image banalization is the process of turning a grayscale image into a black-and-white image[26] . A grayscale image can have pixel values between [0.255], which equates to 256 distinct intensities. Each pixel in binary graphics (Black/White) is assigned to either black or white. By applying a threshold to the gray image, it is normal practice to convert grayscale to black and white. The values of each pixel in a picture are compared to a predefined threshold value when a threshold is applied. Each pixel value is set to zero if it is below the first threshold and to one if it is above it. After completing this process, every pixel in the image has either a value of zero or one, creating a binary.

5.4. Thinning

The image is thinned after the binarization procedure, which is yet another crucial pre-processing method. Ridge thinning is the removal of superfluous pixels from ridges until they are only one pixel wide. Iterative and parallel thinning algorithms are used. It represents a 3×3 window moving along the image, with computations conducted on each pixel to determine whether or not to stay in the image. In the window, the pixels surrounding the center pixel are explained and categorized. Until the image achieves a stable state, the algorithm executes two sub-iterations constantly. Other morphological treatments are applied to the thinned ridge map to remove isolated points, H breaks, and spikes. Noise processing means that any single points, whether they are single-point breaks in a ridge or single-point ridges, are removed in this stage.

5.5. Feature Extraction

Getting a fingerprint's core point is the initial step in the real minutiae extraction procedure. The following is an illustration of the main notion of the core point determination: The highest curvature on the convex ridge can be described as the reference point that's usually existing in the middle area of the fingerprint.

The highest curvature can be found using sophisticated filtering methods, which can then be used to pinpoint the location of the reference point. Several complicated filters are applied on orientation field of the ridge produced from the original image of a fingerprint. A reference point can be defined as the filtered image that reacts to the most intricate filter. Since each output is unique, this output point serves as a reference (core point).

Once the binary picture has been obtained, a quick image check can be done to find the exact matching pixels. To extract the ridge endpoints and bifurcations of minutiae, the immediate neighborhood surrounding each pixel representing a ridge in the image is searched. As a result, for each minutia, three pieces of information which are x and y coordinates of minutiae location are sorted for both minutia type such as a termination represented as type 1 while a bifurcation represented as type 2.

6. EXPERIMENTAL RESULTS

The presented work implemented by using MATLAB 2019 program. The performance of the suggested system based on biometric authentication approaches is presented in this section. There are two main metrics used to evaluate the effectiveness of the biometric authentication system in order to validate the strength of the proposed system. The False Rejection Rate (FRR) is the first, while the False Acceptance Rate (FAR) is the second (FAR). FRR stands for "failure to authorize a person who is already authorized." Giving authorization to an unauthorized person [27] is what the FAR refers to. Both FAR and FRR must be kept as low as feasible, yet they are adversaries who must be balanced. Table 3 shows the comparison in techniques/ algorithms used, used data base and (FAR, FRR) results between our approach and author with their corresponding approaches.

Table 3. Comparison in FAR, FRR results between bat algorithm and other techniques

Authors	Techniques/ Algorithms Used	FAR	FRR	Data Base
Our Approach	The bat algorithm	0.001%	0.007%	FVC2002
Lili Liu and Tianjie Cao (2012) [28]	Gabor filter-based Enhancement and CN concept for Mi-nutiae Extraction	0.085%	1.4%	2000 fingerprint images of 200 in-dividuals at 500dpi
F.A. Afsar, M. Arif and M. Hussain (2004) [29]	Gabor filter based Enhancement and CN concept for Mi-nutiae Extraction	1%	7%	FVC 2000 800 fingerprints from110 different fingers
Ishpreet Singh Virk and Raman Maini (2012) [30]	Histogram Equalization for enhancement and CN Concept for Minutiae Extraction	0.06%	6.9%	FVC2000

As shown in Table 3, Our method is better when comparing results with [28-30] based on FAR and FRR values, due to the quality of the features chosen by the bat algorithm.

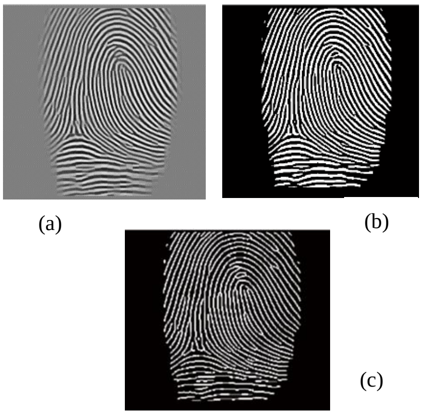

Figure 2. a, b and c enhanced, Binarized and Thinned fingerprint, respectively

7. CONCLUSION AND FUTURE WORK

Like all other automatic systems based on images, Features Extraction is crucial in any fingerprint system, in particular, since input images are generally affected by the acquisition process like most other biometric systems. Distortions are induced due to this process because of many parameters. These introduced distortions on the level of ridge structure would affect the spatial locations of minutiaes, the representatives of distinctive fingerprints. Hence, the output (decision) of the minutiae-based system is affected. The features extraction for fingerprint images has been suggested and presented in this paper using the (BA) technique. The BA method is used to search the image's feature space for the optimum features vector. Several factors have been taken into account when estimating performance, including the features chosen, the measurement and recognition rate of the preferred feature, and the training time period. The acquired results demonstrated the high quality of the features retrieved using the BA algorithm, as well as the superiority of this optimization strategy in terms of performance speed and work time. In the future, more research into this field will be conducted using the same BA algorithm to extract unaltered aspects of the human face, such as the shape or dimension of the ears, or the color of the iris. Because of the optimization technique's higher performance, the time it takes to recognize or classify individual characteristics will be reduced. In addition, the proposed method might be expanded to handle color images or develop color descriptors.

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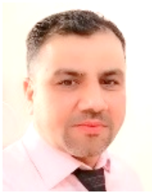

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