A Novel Approach to Fingerprint Identification Using Method of Sectorization

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Abstract- Fingerprints are one of the most popular biometrics traits. Feature extraction and vector creation are crucial in fingerprint-matching algorithms. For increasing the confidence of fingerprint recognition, different feature vector forms are considered in literature. In this paper, we introduce a complete (fully-implemented) algorithm for fingerprint recognition. The work describes image preprocessing based on our previous works and feature vector creation that bases on sectoralization. The image preprocessing includes filtering, skeletonisation, minutiae extraction by CN (Crossing Number) algorithm and spurious minutiae removal. The feature vector creation is based on dividing the fingerprint into sectors. The division is done on the basis of image height.

Keywords - biometrics, fingerprints, feature extraction, minutiae, sectoralization, feature vector, image processing

I. INTRODUCTION

Fingerprints are one of the most popular human features in biometrics safety systems. One can easily notice these safety procedures in our everyday life. For example, new smartphones include a built-in fingerprint scanner. Recent research is showing that users like this way of unlocking their phones. In their opinion it is really simple to use although it provides high-level security. Fingerprints are universal, unique, hard to spoof and can easily be obtained with scanners. This human trait is one of biometrics main interest area.

During the last 20 years, huge interest in fingerprint recognition was observed. The increase of this feature popularity caused a huge progress in fingerprint identification and processing algorithms. Moreover, fingerprint scanners are easily observable in everyday life. Right now, smartphones, laptops and much more different devices contain this solution. Mentioned trend is caused by decreasing cost of biometrics devices and increasing data quality obtained with them. What is more, biometrics safety systems can provide high-level identification (or verification) accuracy. This feature is crucial for such system users. The algorithm presented in this paper is the first step in creation of an efficient, easy-to-use and effective fingerprint processing and identification algorithm. Preprocessing part of this solution is based on authors' previous work although it contains a few additional new steps. Feature vector was created with the usage of sectoralization. This way more complex feature vector can be presented. For the purpose of this paper, the full algorithm was implemented, from the binarization to the feature vector generation.

The paper work is organized as follows. Known approaches are presented in Section 2. In Section 3, authors' solution is presented. Section 4 contains the analysis of the obtained results. Lastly, a summary and future work are presented in Section 5.

II. KNOWN APPROACHES

Lately more interest in the field of fingerprint recognition has been observed. To account this, the authors of this paper decided to present some of recent approaches in fingerprint identification and preprocessing algorithms.

In [1] authors proposed an approach that combines subjective human analysis with a statistical test of the result. authors' idea relies on the hypothesis that there are limits to the distortion caused by skin stretch. The authors modelled this kind of limits with multivariate normal probability density function to the distances and angle formed by a marked ridge characteristics and the two closest neighboring minutiae. This work provides an idea tested within 5 users.

Another interesting algorithm is described in [2]. The authors consider a multimodal biometric system based on two features obtained from a multi instance fingerprint scanner. These traits are fingerprint and time dynamics associated with fingerprint acquisition. Authors provided user verification and spoof resistance experiments. These experiments were done with ATVS and LivDet-13 fingerprint databases each with fingerprint dynamics database. The performance of the proposed solution was measured with an average EER equal to 0.59% and with area under the curve (AUC) equal to 0.997.

Authors of [3] proposed fingerprint recognition and implementation of their solution in Android environment. The main point of this article is to provide additional security procedures for data retrieval processes. These processes in every application are the part where its actual features are defined. Authors used an external reader for fingerprint acquisition. In this work no specific processing or classification algorithm is described. Authors claimed that they are using a solution provided by Open CV [4] library. No information about the accuracy of using external algorithms were provided.

In [5] authors emphasize the importance of image processing in fingerprint identification or verification systems. This work provides a comparison between different approaches to fingerprint preprocessing. Authors do not consider any low quality input images. In their work it is claimed that if the input image is good, authors' method will produce a good output. This is disadvantage of the proposed approach because it could be considered as a limitation of the

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described method. On the basis of studied methods authors prepared their own solution that consists of preprocessing algorithm. In this approach, authors use operations like: binarization, thinning or dilation. The proposed algorithm is used to detect minutiae. No information about identification or verification accuracy is provided.

An interesting algorithm was described in [6]. Authors of the work pointed that it is reuiired to present flexible, fast identification system based on fingerprints. This is due to the fact that this kind of solution can have high accuracy level. Moreover, it is claimed that fingerprints are commonly used to improve the speed of the identification. In the work a complete system with a hierarchical classification framework that fuses the information of multiple feature extractors was presented. Authors applied feature selection to improve the classification accuracy. During experiments two NIST and a large synthetic database were used. Authors claimed that their approach had no less than 91.89% classification accuracy. Moreover, in the paper two results were obtained and shown - classification accuracy for segmented image (equals 93.76%) and not segmented (91.89%).

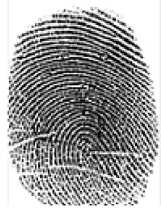
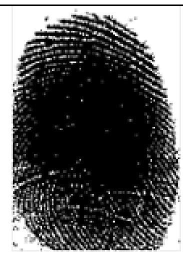
In [7] authors claim the fingerprint preprocessing programs implemented on some embedded systems can be considered as important especially for real time standalone applications. What is more in this work, authors pointed that with real time embedded systems, the time needed to preprocess an image is reduced. In their article simple processing algorithm is implemented on two different platforms: Texas Instruments Sitara AM3359 which is a single board computer and OMAP-L138, which is a development kit. The main point of this article is to compare execution time of algorithm implementations. The obtained results show that the preprocessing with ARM or DSP microprocessors could speed-up the whole fingerprint analysis process.

III. PROPOSED APPROACH

In this section we present the complete algorithm for fingerprint recognition we have worked out. The proposed approach is a continuation of our work introduced in [8]. To measure the accuracy of our solution we prepared our own database that consists of 15 users, each of which is represented by three images of the user's fingerprint.

As the first step of the proposed system, fingerprint image is preprocessed starting with the process is binarization. Authors take into consideration different available algorithms: Manual thresholding, Mean Iterative Selection, Entropy Selection, Minimum Error and Fuzzy Minimum Error [9]. A comparison between the obtained results is presented in Table 1.

TABLE I. COMPARISON BETWEEN DIFFERENT BINARIZATION ALGORITHMS

Original image	***Manual thresholding with t = 180***	***Mean Iterative Selection***
		
Entropy Selection	***Minimum Error***	***Fuzzy Minimum Error***
		

The best results in this step were obtained with manual thresholding method. By this algorithm all elements of the fingerprint are clearly visible and neither of them is connected to one line. Selected method allows to avoid inaccurate representation of fingerprint. In this case one can understand inaccurate representation as a visualization that has crucial impact on recognition classified as false positive.

Another step of the proposed algorithm is filtering. During experiments authors made an observation that the best results (the most informative) are obtained with median filter. This operation is used to remove "salt and pepper" noise. Authors used it with 3x3 mask and this method was made four times on each input image. The binarized image and the one obtained after the filtering step are presented in Fig. 1.

(a) *(b)*

Fig. 1. Image after binarization (a) and image after filtering operation (b)

Filtering provided fingerprint image in quality that enables the next step, the skeletonization, to perform properly. This operation is one of the most important ones because it provides an image that consists of 1-pixel width lines. By this step all unnecessary information from an image is deleted. To obtain high quality results, authors used KMM algorithm [10]. Processing results obtained with this method are presented with the previous step result in Fig. 2.

(a) *(b)*

Fig. 2. Image after filtering step (a) and image obtained with KMM method (b)

Another observation that was made during experiments was that the most informative part of fingerprint is surrounded by redundant white regions. These areas were visible due to the way in which fingerprint was gained by fingerprint scanner. White regions do not have crucial impact on identification result although it usually causes much slower image processing procedure. Besides, these regions are of redundant information character. On the basis of observations made under owned fingerprint database, authors decided to provide two operations by which additional regions are removed. These operations are the ones that cut image width by 10% of each image side and cut image height by 10% from the top and bottom of processed image. Both of these steps are worked out within the authors' algorithm. The obtained results are shown in Fig. 3.

(a) *(b)*

Fig. 3. Image after cutting its width by 10% from each side (a) and after cutting its height by 10% from top and bottom (b)

Another step of the proposed approach could be indicated with "Minutiae finding and spurious "points removal". In this paper the authors proposed minutiae detection with Cross Number (CN) algorithm. This solution is a widely-used approach for minutiae detection. In this algorithm 8 closest neighbors of each analyzed pixel are taken into consideration. The crossing number is calculated as in (1).

$$CN = \frac{1}{2} \cdot \sum_{i=1}^{8} |P_i - P_{i-1}| \qquad (1)$$

With the computed CN number each pixel could be easily classified. When it equals 0, the analyzed pixel belongs to the background, if CN = 1, then the analyzed pixel is a ridge terminal. When CN = 2, it then means it is ridge continuation whilst CN = 3 would inform that this concrete pixel is classified as a ridge bifurcation.

Our database that consists of 45 samples has images of low quality. Due to this fact, several spurious minutiae could be visible. Authors decided to provide an additional step in which all of them are to be removed. This operation is done following exactly the procedure given in a previously published work [11]. The distance that is measured from the closest minutiae of the same type is analyzed. If it is too close and the distance is lower than the proposed threshold then the minutiae is classified as a false one. Authors observed that the best results were obtained with thresholds: 55 – for ridge endings and 40 for ridge bifurcations. An image with detected minutiae is presented in Fig. 4. All ridge bifurcations are pointed with a circle whilst the ridge endings with a triangle.

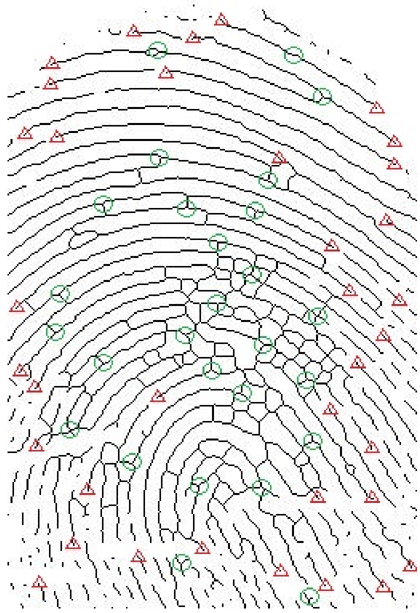


Fig. 4. Fingerprint and all detected minutiae

As the most important part of our approach, feature vector generation has to be worked out. In this solution, authors divided the image into a number of areas. Each area has the same height and width. Width of each area is the same as image width but area height is calculated as in (2).

$$areaHeight = \left\lfloor \frac{imageHeight}{numberOfAreas} \right\rfloor \qquad (2)$$

The way in which the processed image is divided is given in Fig. 5. In this figure image is divided into 13 areas.

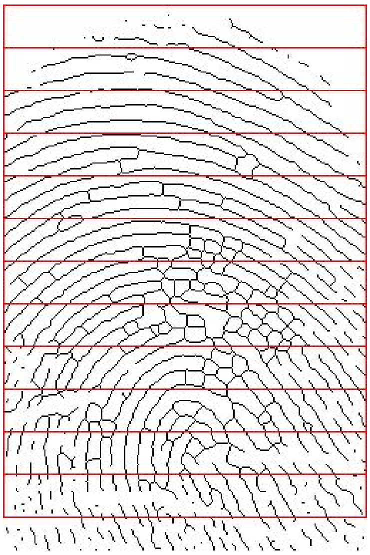


Fig. 5. Fingerprint image divided into sectors

On the basis of areas number the feature vector is generated. In each area the minutiae number is calculated. Then starting from the first area, the number of minutiae is added to the value from the previous position (for first area, nothing is added) and it is stored in the feature vector on a position that corresponds to the analyzed area number.

IV. RESULTS OF THE EXPERIMENT

Authors' database consists of 45 samples, each user is described by 3 fingerprint images. During experiment our database was divided randomly into two parts – training set consists of 23 samples and testing set with 22 samples. In this paper authors considered sectors with different width, from 20px to 80px. For each of them the classification accuracy was measured. The obtained results are presented in Fig. 6.

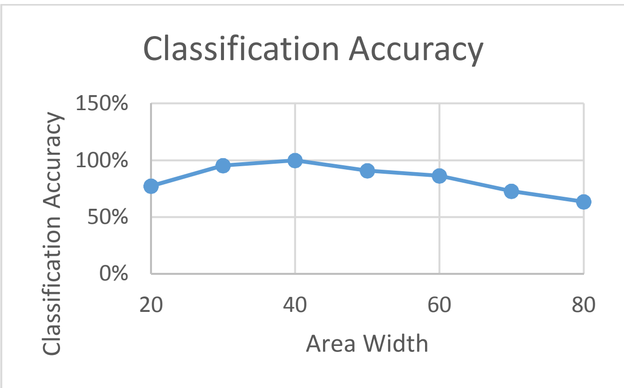


Fig. 6. Classification accuracy based on area width

After dividing the set into two groups, the distance between testing sample and each from training set was measured. Computation is done with Euclidean metric. The distance d between two samples is calculated as in (3).

$$d = \sqrt{\sum_{i=1}^{n} (testing_i - training_i)^2} \qquad (3)$$

The best ratio was obtained with area width of 40px. Figure 6 presents classification accuracy for different area width. Different sector width provides distinct number of sectors. The accuracy of proposed approach reached 100% when area width equals 40px. This result has exceeded authors' expectations for such small size of data. One can easily claim that value for 40px is the maximum presented in the chart. After the best threshold classification, accuracies for each next area width are decreasing. The least accuracy results were obtained with 80px area width.

In Fig. 7 the results for different number of samples in the training set are presented. As in the case of the chart presented in Fig. 6, the one presented in Fig. 7 also has one maximum obtained for 23 samples in the training set. As it can easily be observed from the figure, when decreasing the number of training samples, the number of testing samples is increasing.

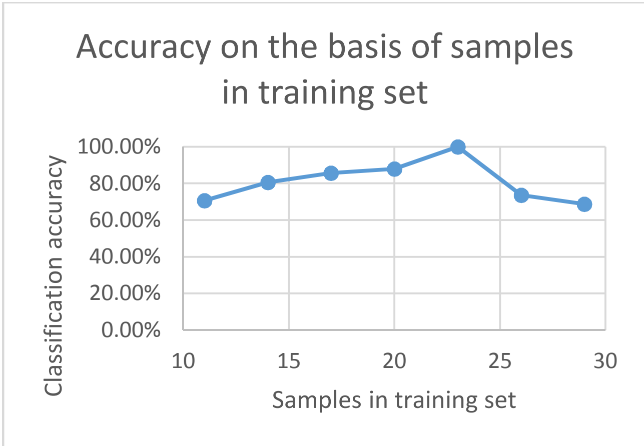


Fig. 7. Classification accuracy based on number of samples in training set

The same is in the opposite situation, when the testing samples number is decreasing, the training number is increasing.

V. CONCLUSIONS AND FUTURE WORK

Biometric methods present a very convenient way to increase the safety of computer system. Systems secured with passwords can be easily broken because of different hacking strategies, for instance SQL injection or brute force. If it comes to Biometrics, spoofing of human traits is not so simple. Moreover, newly created biometrics scanners are taking into consideration not only the human trait but also some additional differentiators like the measured feature lifespan or temperature of the studied object. Biometrics methods, as known, are of either identification and verification type. If it comes to identification it is often a computationally difficult process. It is connected with studying the whole database. Identification algorithms have to be fast and robust.

In this paper, authors prepared a new way to reach satisfactory level of identification accuracy. To measure distances between different samples, Euclidean metric was used. Classification result was obtained with the simplest form of k-NN algorithm that is 1-NN. This solution perfectly matches the requirements of algorithm speed and reliability that were already mentioned earlier.

As it was presented, our algorithm for a certain sector width can have 100% of accuracy. Authors used sectoralization to divide fingerprint due to the possibility of getting more complex feature vector. Moreover, this approach provides more information about fingerprint and gives possibilities to obtain areas from fingerprint that contains significant data. It means that we will take into consideration only the areas that contain minutiae. Our database is still expanding. Existing users are leaving more of their samples that are different fingerprints. What is more, new users are also leaving their samples. It is the authors' policy to publish their database online, and we hope this will take place in the very near future.

The authors are also planning to take into consideration additional minutiae types and dynamic division of the fingerprint image. We believe that the analysis of minutiae number in different sectors would enable us to dynamically divide the image into areas. This way we would consider not only the feature vector but also the pattern of sectors. Additionally, as an extension to this research we would like to introduce more complex decision algorithm and take into account the users with different pathological changes in their fingerprint patterns. We believe that the usage of Artificial Intelligence will also enhance our method and increase the solution accuracy.

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