International Journal of Computer Sciences and Engineering Open Access
Survey Paper Vol.-6, Issue-8, Aug 2018 E-ISSN: 2347-2693

Fingerprint Matching Algorithms and BOVW: A Survey

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Available online at: www.ijcseonline.org

Accepted: 15/Aug/2018, Published: 31/Aug/2018

***Abstract*—** In recent years, the use of biometrics has increased exponentially in the areas where security is a playing vital role. The factors that increasing the use of biometric in many applications include: the cost of the devices which are used for capturing and storing the images are greatly reducing, the ease-of-use of available devices, availability of fast hardware devices which are used for computing, the increasing use of networking and internet technology, different algorithms are available for storing the images in compressed format, etc. The role of biometric application is to authenticate the person by their voice, face or fingerprint. In biometric system, finger print is an extensively accepted one because of its advantage like no two person's finger prints are same in the universe. In this paper we are presenting the detailed survey on fingerprint matching algorithms.

***Keywords*—** Fingerprint matching, Fingerprint verification, Fingerprint identification, Fingerprint classification, Bag-of-Visual-Words.

I. INTRODUCTION

The discovery of new technology triggers to get a lot of volume of data to the society in various forms. The sources like sensors, scanners, satellites, internet, etc. are producing the data image databases. several researchers and practitioners doing the image mining with the purpose of understanding the patterns in it, extracting the specific information, recognition of things in image, identifying the hidden things in image, etc. Image mining is used in many application areas including in law enforcement applications, forensic criminology (finger print identification, face recognition, authentication etc.), robotic and industrial automation (robotic vision), medicine (understanding X-Rays, CT scans, MRI scans, etc.), meteorology, and education (visualization) as well as in geography (satellite imagery). Image mining is different from mining text data as it inherently differs in storing images, retrieving the images, and indexing the images and as a result of these characteristics it is challenging to mine and extract the hidden information from the images. Image mining is an interdisciplinary area and it uses data mining techniques, database technology, computer vision, machine learning, statistics, image retrieval, image processing, artificial intelligence, etc., and it consists of different components, including pre-processing the image for enhancing the quality of image, classifying the images for , image indexing, retrieval of images, data management, etc. Researchers and practitioners proposed a lot of techniques and methods to the above mentioned procedures.

In recent years, the use of biometrics has increased exponentially in the areas where security is a playing vital role. The factors that increasing the use of biometric in many applications include: the cost of the devices which are used for capturing and storing the images are greatly reducing, the ease-of-use of available devices, availability of fast hardware devices which are used for computing, the increasing use of networking and internet technology, different algorithms are available for storing the images in compressed format, etc. The role of biometric application is to authenticate the person by their voice, face or fingerprint. The biometric system is favored compared to traditional identification systems like password or Personal Identification Number (PIN). In biometric system finger print is an extensively accepted one because of its advantage like no two person's finger prints are same in the universe.

In general the data acquired from the biometric devices like CCTV, CT scans, and MRI scans, etc, contains lot of noise [1, 2]. There are three main reasons for affecting the quality of image with respective fingerprint images: the appearance of ridges (these are the lines in the fingerprints), the space between the ridges (these are called as valleys), at ridge ending (it is the point where a ridge is terminated) and ridge bifurcation (it is the point where the single ridge is split into two paths and it looks like a Y-junction and all these are shown in figure-1). The quality of the image is improved by

improving the contrast among the ridges and valleys, and also by reducing the noise in the images [3, 4]. Ridges play vital role in finger print matching, as one the ridges of one finger print is matched with the ridges of another fingerprint. It is evident step in fingerprint processing. After enhancing the fingerprint image for processing the image it is necessary to extract the features for matching purpose and it can be happened in three ways, one is by using minutiae [5, 6, 7], second one is by suing the images [8, 9, 2], and the third one is by combinations of both i.e. hybrid method [10, 3, 11].

Figure-1: Ridges, valleys, ending and bifurcation in fingerprint images (source from Google)

II. FINGERPRINT VERIFICATION AND IDENTIFICATION

In fingerprint area people are proposed two types of algorithms, identification and verification. Fingerprint verification is matching of applicant's fingerprint with the enrolee fingerprint. To do this task, a person has to register his/her fingerprint into the database in a compressed format along with his identify. Fingerprint verification is also called as one-to-one matching. Fingerprint verification is generally used for authenticating the user for accessing the resources. Most of the fingerprint verification techniques use the method of comparing the neighborhoods of nearby minutia. Each minutia has its own types of attributes and also minutiae direction. If the result of the comparison indicates only a small fraction of differences between the neighborhoods of the applicant's fingerprint with the enrollee fingerprint and is considered as a match. The process of matching all the combinations of neighborhoods exhaustively searched, and if enough similarities are found then it can be declared as a match. It is rare that the match of 100%, since the images are exposed to noise and change of skin elasticity. There are so many fingerprint verification algorithms exist in the literature [12, 13, 14, 15]. In [7], authors use the features extracted from the WFMT (Wavelet and Fourier-Melling Transformation). In this, the Wavelet transformation is used to retain the local edges and to lessen the noise.

Fingerprint identification is the process of matching a fingerprint of unknown person against the set of fingerprints (a database of fingerprints) which are all known fingerprints, and is also called as one-to-many matching. One solution for fingerprint identification is by using the fingerprint verification method to each and every image in the database is considered as enrollee fingerprint, but it is practically difficult because of exhaustive search. One solution for this problem is in the first step based on the pattern the images in the database are divided into groups and the same is followed for test fingerprint. Pattern based matching is done between test fingerprint and the database fingerprints of the same pattern, and it save lot of time in matching the non-matches.
An informal third type of fingerprint matching approach is also there in literature named as one-to-few matching, is generally used by few users, like family members can use to enter their own house. Here few refer the value between five and twenty.

Fiure-2 shows the steps in processing the fingerprint; initially the collected sample fingerprint is undergone to pre-processing techniques for improving the quality of image. In the second step the enhanced fingerprint image is used to extract the features. With the help of these features the relevant algorithm (verification or identification) is applied to get the score to indicate the percentage of matching. Compared to the fingerprint verification fingerprint identification is a complex task.

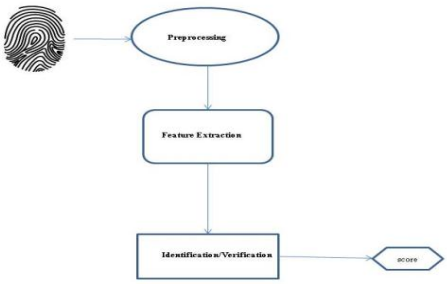

Figure-2: Steps in fingerprint processing

III. FINGERPRINT CLASSIFICATION

Nowadays, the number of fingerprint images in fingerprint database is increasing greatly from day to day and it heavily increases the computational time of fingerprint recognition. To overcome these most of the researchers are used classification and indexing techniques [16]. Classification is used to identify the pattern of fingerprint and is generally considered as a prerequisite step to fingerprint identification or fingerprint verification and this classification greatly reduces the complexity of the matching process. Using the global patterns of valleys and ridges the fingerprints are categorized. Galton (1892) originally proposed the use of three fingerprint classes: the arch, the whorl and the loop for classification purpose and are shown in the following figure-3.

After a few years later the classification is based on Henry's classification [17] and is based on eight classes: Accidental Whorl, Central-Pocket Whorl, Plain Whorl, Double Loop Whorl, Right Loop, Left Loop, Tented Arch and Plain Arch. The accidental class is used by Henry to

describe the less number of fingerprints that are unclear and do not fall clearly into any of the other categories. Some of the Henry's classification is shown in figure-4.

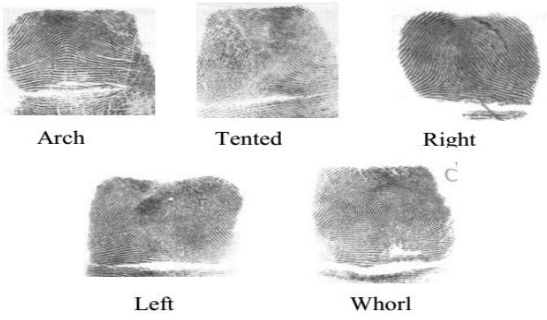

Figure-3: Fingerprint patterns: Arch, Loop and Whorl (Galton's three classes)

There are many categories of classification approaches in the literature and the following are the most popular ones:

A. Model based approaches – The classification is based on the number and the locations of singular points. In [18] the authors proposed a method which works in the following manner.

a) Using the 9 X 9 mask compute the ridge directions.

b) Using the Poincare index find the singularities in directional image.

c) Using the detected number and singular points [19] classify the fingerprint.

In this, global features (singular points) of the fingerprints have been found more effective in classifying the fingerprints into different known classes.

B. Structure-based approach – In this approaches the classification is done using the estimated orientation fields. The structure-based approaches are known to partitions the fingerprint orientation regions and the regions governed by graphs [20]. Mainly, it consists of two types – namely syntactic pattern matching and graph matching.

i. Syntactic pattern matching – In this, an analogy is drawn between the structure of the input data and the language syntax. Sequence of primitives is used to represent the input data, which is considered as a sentence of the language. By determining which grammar most likely produces a given input sequence, classification is performed.

ii. Graph matching: A model graph is constructed for each finger print class. By applying graph matching algorithm, we can check whether two graphs are isomorphic or not.

C. Combined approaches – In these methods different approaches are combined to improve the performance of classification. For example, combination of structural and statistical features. Using line tracing algorithm structural features are extracted from the orientation field. String of symbols is used for important flow lines are represented by strings of symbols that encode information about their endpoints and curvature. A three-layer feed-forward artificial neural network with six sub networks (one for each class) is used for classification.

D. Neural network approaches – Neural network is the one of the standard approach used in machine learning and data mining areas to classify the data. The neural network approach is based on the multilayer perception and in fingerprint classification also neural network approaches playing critical role and most of the neural network works are based on minutiae approaches. For learning and classification, neural networks offer fuzzy logic techniques. In this, Fuzzy logic rules are automatically generated during training period. This approach is based on the singularity features that include the number of core and delta points, the orientation of core points, the relative position of core and delta points and the global direction of the orientation field.

Research community also developed different types of neural based classification approaches:

i. Pattern- level Classification Automation System for Fingerprints (PCASYS) system developed by NIST and FBI uses core of loops, the upper core of whorls, arches and tended arches. With respect to the centre of the fingerprint image, directional image is registered. KL transform, PNN (Probabilistic Neural network) is used to reduce the dimensionality of the orientation field and classify the feature vector.

ii. On the basis of their discrete wavelet transforms, Hugo [27] suggested a feed-forward neural network which was trained to classify fingerprints.

iii. Self Organizing Map (SOM) or Self Organizing Feature Map (SOFM) is used to reduce dimensionality reduction and is depends on the Kohenen map or networks.

Recently in pattern recognition and in machine learning researchers are using a new technique named as Bag-of-Visual words (BoVW) as feature extraction [21, 22, 23, 24]. In this BoVW model a set of visual words are identified by clustering the local feature descriptor of the images. Generally Speed-Up Robust Feature Transform (SURF), Scale Invariant Feature Transform (SIFT), is used to extract the features. In [25] the authors proposed a method for classifying the fingerprint images using the BoVW model, and their approach is described in the following:

1. The quality of the fingerprint images are enhanced using the CLAHE [26] algorithm.
2. By using the k-means and k-mediods algorithm and using the other clustering algorithms the descriptors are extracted.
3. In the third step the Bag-of-Visual-Words are stored in the database.
4. Using the Back propagation algorithm the fingerprint images are classified.

IV. CONCLUSION

In this paper we discussed in detailed about the fingerprint matching algorithms and mostly we considered the fingerprint verification, fingerprint identification and fingerprint classification algorithms exist in the literature.

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