Fingerprint Classification by using the Delaunay Triangles

Y. Suresh, S. V. N Srinivasu

***Abstract*: The use of biometrics has increased drastically with the evolution in hardware and software technology. Matching of finger prints are used for two types of system is used for two types of applications; one is finger print verification and another one is finger print identification. The fingerprint identification is computationally expensive one. In this paper we are proposing a approach for fingerprint classification and our main contribution in this paper is we consider the cost of minimums spanning tree constructed using the set of points represents the ridge bifurcation of ridge endings of the fingerprint and also we considered the special points which are participating in more than s triangles in Delaunay triangulation.**

Index Choice: Biometrics, Finger prin, WFMT, Delaunay Triangle

I. INTRODUCTION

The use of biometrics has increased drastically with the evolution in hardware and software technology. The role of biometric application is to authenticate the person by their face, voice or fingerprint. The fingerprint system is the preferred one due to advantages. Fingerprint is a popularly accepted one due to its advantage like no two person's finger prints are same in the universe.

Matching of finger prints are used for two types of system is used for two types of applications; one is finger print verification and another one is finger print identification. In fingerprint identification the inputted fingerprint is compared with the target fingerprint and is considered as one to one matching (1:1) and is computationally less expensive. In fingerprint identification system the given fingerprint image is matched with the fingerprint image in the database and is considered as one to many matching (1: N). Among these two the identification is computationally very expensive operation. The advantage of fingerprint identification process is that the fingerprint pattern is same for a person throughout his/her life, making it a foolproof method for human identification.

In recent years, the number of fingerprint images captured and stored in a database is increasing significantly and results in increasing the time for fingerprint identification process. The classification techniques are used to overcome this limitation. By using any classification technique the given image database is divided into classes and each class contains the subset of fingerprint images. At the identification time the given source fingerprint image is matched with the subset of the images instead of all the fingerprint images in the database and it greatly reduces the computational time of the identification process. Henry's classification is the one for most of the researchers for classifying the fingerprint images and is of eight classes: Plain Whorl, Central-Pocket Whorl, Accidental 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.

Ridges and Valleys are also the two most important characteristics of the fingerprint which guides to differentiate the given fingerprints. Ridges are the dark lines in fingerprint and the valleys are the bright lines in the fingerprint. The figure-1 presents the ridges and valleys in a fingerprint image and figure-2 presents the ridge ending and bifurcations.

Delaunay triangulation is the one of most popular approach is geometric applications, where the given sets of points are divided into regions of triangles. It has many interesting properties and it attracts the many researchers to use them in different applications to solve the problems and image mining is not an exception too. Many researchers are used the Delaunay triangulation in fingerprint system to develop new approaches for verification or identification system and most of the approaches used the minutiae information of fingerprints.

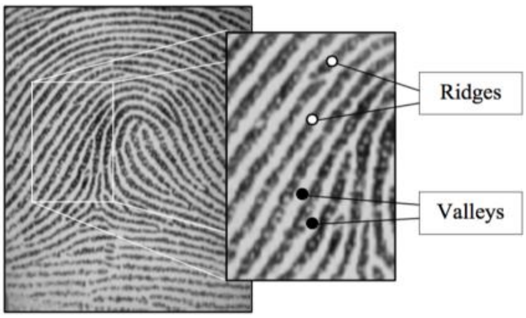

Fig 1: Ridges and Valleys in fingerprint. Figure from [16, p.97]

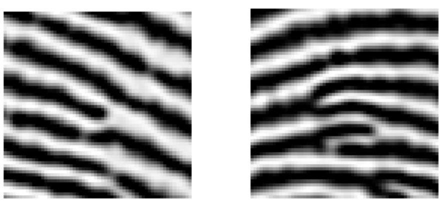

Fig 2: Ridge ending and Ridge Bifurcation

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In this paper we proposing a approach for fingerprint classification and our main contribution in this paper is we consider the cost of minimums spanning tree constructed using the set of points represents the ridge bifurcation of ridge endings of the fingerprint and also we considered the special points which are participating in more than s triangles in Delaunay triangulation.

II. RELATED WORK

Bag of Visual based approaches

Thanh-Nghi Do et. al. in [1] presents the issue of large number of visual words. For classification purpose they used the decision trees. He et. al. [2] presented an approach for fingerprint retrieval based on the concept of Bag of Visual Words and they used several descriptors for extracting the visual words.

Minutiae based algorithms

Minutiae based approaches are more popular approaches in the fingerprint verification and fingerprint identification techniques. Most of the approaches used the Delaunay triangulation based methods to identify or verify the given query fingerprint. Parzile, etc. al., in 2004 [3] each minutiae considered as an vertex in the triangle, and they measures the distance between minutiae pairs, angles between the minutiae pairs, etc. are used in their approach. By applying the three different filters they selected some subset of the triangles to compare with the triangles in the given query fingerprint. Liu et al. [4] proposed a similar approach for matching the fingerprints based on Delaunay triangulations. They used the concept of RMPs (reference minutiae pairs). They tried to find the similar edge pairs from the given query fingerprint and the template set of minutiae. In [5] Deng and Huo proposed another approach based on Delaunay triangulation, instead of considering the best minutiae pairs they tried to find the matching edge pairs.

Image based approaches

In [6], 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. Karthik Nanda kumar et. al., in [7] presents a correlation-based fingerprint matching algorithms that uses the local correlation of regions around the minutiae for estimating the amount of degree of similarity between given two fingerprint images. Abdullah Cavusoglu et. al [8] proposed a robust Fingerprint Matching approach for verification based on correlation. A variance based segmentation method is used to segment the given fingerprint image.There are so many fingerprint verification algorithms exist in the literature based on the geometric properties, genetic algorithmic type approaches, etc. [9, 10, 11, 12, 16].

III. CLASSIFYING THE FINGERPRINT IMAGES

Triangulation is the more popular approach in most of the geometric applications [13]; it is the process of dividing the given region of space into sub regions of triangles, here we considered only 2D regions, since we are considering the minutiae points in the fingerprint image.

Construction of Delaunay Triangles: The following general approach followed in literature for constructing the Delaunay triangles [14].

i. Given n points of each is a two dimensional point, S = $\{p_1, p_2, \ldots, p_n\}$.
ii. First compute the Voronoi diagram using the points in S. It divides the 2D space into regions of each point such that all the points (p_j, p_k, …) in the region of p_i are closer to p_i only than to any other points region in the set S.
iii. Using this voronoi diagram and by connecting the centers of every pair of neighboring voronoi regions the Delaunay triangles are constructed.

The following figures 3, 4 and 5 shows some set of 2 dimensional points and their Voronoi diagram, and the respective Delaunay triangulation.

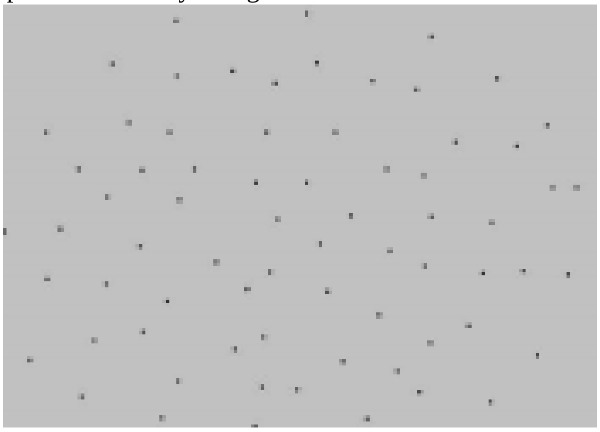

Fig 3: Set of two dimensional points

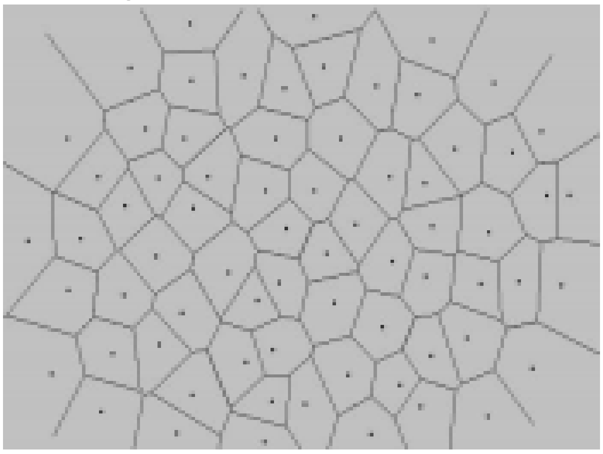

Fig 4: Voronoi diagram

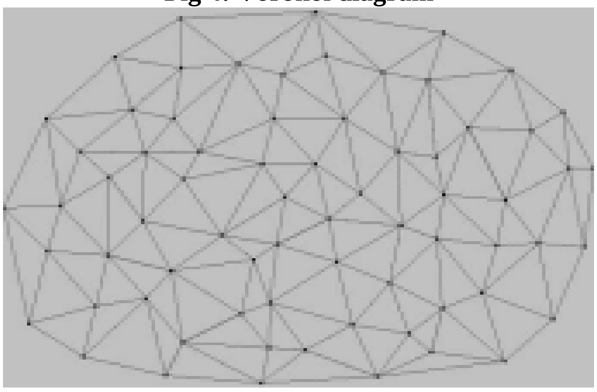

Fig 5: Delaunay Triangulation

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The Delaunay triangulation follows some properties,

i. The Delaunay triangulation of a non-degenerate set of points is unique;
ii. A circle passes through the three points of a Delaunay triangle contains no other points.
iii. The smallest angle among all the angles in all triangles in Delaunay triangulation is greater than the minimum angle in any other triangulation of the same points.

Any edge in Delaunay triangulation belongs to at most two polygons or triangles, so the total number of triangles generated by the Delaunay triangulation is also in linear with respective to the number of 2D points.

Minutiae Triangulation

The most important features of fingerprint system are minutiae. Ridge ending and ridge bifurcation are the two most prominent features used in minutiae's of the fingerprint system and each minutiae in 2D space are represented by its x and y coordinates. By using the algorithm in [15] the minutiae have been extracted, and their Delaunay triangulation is computed. The following figure X shows the resultant Delaunay triangulation of the minutiae found from a sample fingerprint.

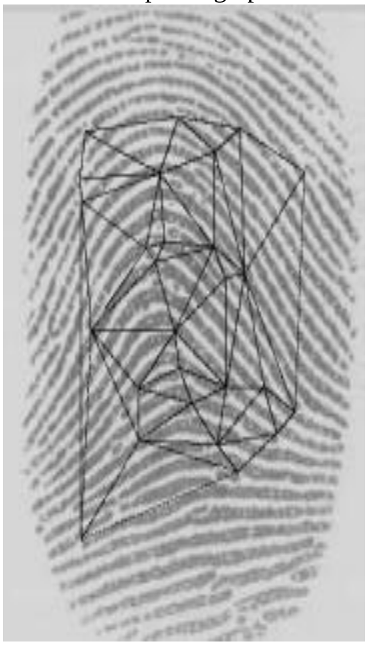

Fig 6: Delaunay Triangulation of minutiae

Construction of vocabulary

We assume all the fingerprint images consider for input are already insensitive to rotation and scaling (means all the input images are in the same size and all are captured with same measures). In any image or fingerprint classification approach, the prerequisite is the extraction of the features of the fingerprint which are the key or significant points in the fingerprint. In our approach we consider the minutiae of a fingerprint are the features of the fingerprint image. The ridge ending and ridge bifurcation are the two most important ones in minutiae of a fingerprint. From the captured fingerprint all the edge endings and edge bifurcations are identified by using the algorithm specified in [5]. "Any picture is a worth of thousand words…" Any image can be represented as mathematically in terms of features, where each feature is represented with a certain frequency of occurrence.

After identifying the minutiae details of all the fingerprints the Delaunay triangulation is constructed using the approach discussed in the section 3.0. We are interested in Delaunay triangulation because it satisfies a number of interesting properties. We are interested in the following property.

Property – 1: With a given set of points P, we may have more than one Delaunay triangulation, but there are certain edges that are present in every Delaunay triangulation of given set of points P.

Property-2: Every Delaunay Triangulation of the give set of point s P contains the Euclidean minimum spanning tree of a P.

Each fingerprint is stored with the following details:

i. The identity of the fingerprint (the persons ID).
ii. The total number of edge endings represented by E.
iii. The total number of edge bifurcations represented by B.
iv. The Euclidean minimum cost of Euclidean minimum spanning tree.
v. For each point p in P, the total number of points participating in s or more number of triangles.

Note: the above information is normalized to a scale of 0 to one.

The things that are used to describe an image are called visual words. Thus, any fingerprint image is combination of these set of visual words. In our terminology each fingerprint is combination of the frequency of ridge endings, ridge bifurcation, and the cost of the minimum spanning tree. To make it more understandable the data is presented in the form of histograms. All the fingerprint images are processed and stored with the above details and is considered as the vocabulary of the database.

Classification of fingerprints based on vocabulary generated

Training the machine to understand the fingerprints using Decision tree and with the appropriate selection measures: Each fingerprint is stored with the details shown in section 3.2. All these five details (words) are used to describe the fingerprint. Here any standard classification algorithm can be used for classification purpose; in our implementation we used the Decision Tree classifier to classify the fingerprint images in the database and we considered except the identity of the fingerprint other four are considered as parameters.

3.3 Identification of query fingerprint image

The following procedure is followed to identify the given query fingerprint:

i. Extract all the minutiae details from the given query fingerprint.
ii. Construct the Voronoi diagram and also construct the Delaunay triangles.
iii. Identify all the details mentioned in 3.2.
iv. Using these details as features apply it to the classification algorithm build in 3.3.
v. Output the fingerprint it is matched.

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IV RESULTS & CONCLUSION

The set of fingerprint image dataset is constructed from the volunteers who gave sample of fingerprints from multiple fingers and is used for verification process. All the samples are labeled and these labels reveal the identity of the person. Here we took the samples from the 23 people and we registered the fingers of thumb and index finger from both the right and left hands. We collected totally 46 samples.

We tested our approach with the dataset on several iterations and the following are the results we achieved:

Trail	Correct	Wrong
1	72.50%	27.50%
2	69.50%	30.50%
3	74.50%	25.50%
4	71.60%	28.40%
Average	72%	28%

Table – 1: Test Results

The above table-1 shows that the algorithm is successful in identifying the correct fingerprint in 72% of the times. This may not be up to the mark, but in future we will try to improve the efficiency of the algorithm by including the more features into the classification algorithm.

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