A Simple and Stable Method of Creating Fingerprint Features With Image Rotation

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Abstract: *The main purpose of the classification of fingerprints is to devise a formula by which a given collection of fingerprints can be tracked and registered. To accelerate the system for classifying fingerprints, it is necessary to utilize fingerprint image characteristics and avoid the different fingerprint forms arising from fingerprint rotation. This paper presents a simple, new approach to the extraction of characteristics from fingerprint images. The proposed method demonstrates that, for a given image, the features remain constant even after being subjected to a wide range of rotations; thus, it creates an array of characteristics which can be used to identify a person from their fingerprint. To achieve this goal, a basic hit-and-miss operation with different structural components is used to detect and count various features in the fingerprint picture; these features are directly identified based on the texture of the fingerprint. The chosen features are used to index the finger image by generating a frequency of occurrences for each one, such that every fingerprint is represented as a vector of these features. The application of the proposed method shows efficient utilization of execution time and memory usage.*

Keywords: *Fingerprint features, hit-and-miss, bifurcation, isolated point, crossover, connected points.*

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1. Introduction

Biometric systems are increasingly substituting conventional password- and token-based authentication methods. When designing a biometric system, safety and accuracy in recognition are paramount [22], and in this regard a person's digital Fingerprints (FP) are among the most reliable and widely used biometric identifiers. FP have crucial and critical uses, with the banking sector, identity verification systems, and the Internet of Things fingerprint identification systems being the most important (see Figure 1) [2, 18].

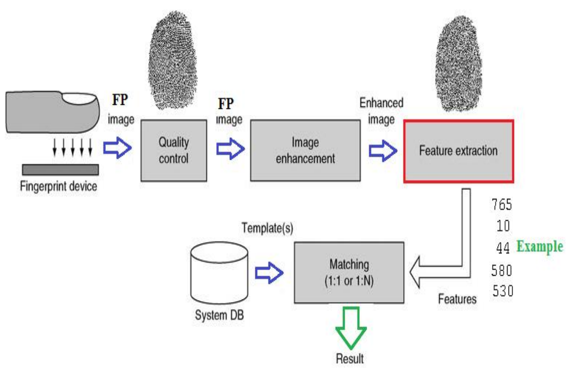


Figure 1. FP classification system.

The tendency of FP to be rather large has a detrimental impact on the classification system's (recognition) efficiency; hence, they need to be represented by a minimum number of values in order to be categorized and the individual concerned identified [2, 5 , 7, 19, 24]. Since FP characteristics are employed to represent fingerprints, the FP recognition system's database size can only include a small and distinct set of fingerprints. Values facilitate the training process and speed up the identification system's ability to make the right call by recognizing the individual more quickly using the characteristics vector.

It is the purpose of this study to present a texture-based approach to extracting FP features, where the features themselves are structured according to the FP's constituent objects [4, 20]. In an FP picture, a collection of items can be found known as minutiae, which may be further broken down into subtypes such bifurcations, ridge (point) endings, solitary points, cross points, and linked points (see Figure 2).

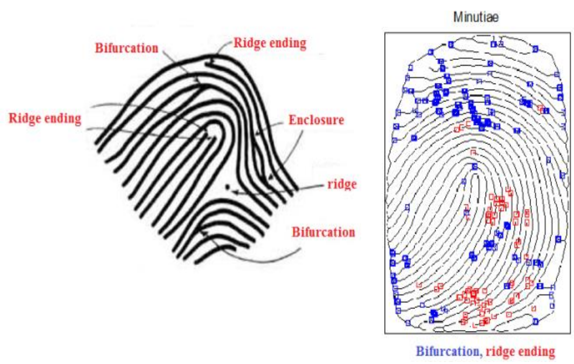


Figure 2. FP image structure.

The most popular objects are analyzed in this paper, as shown in Figure 3.

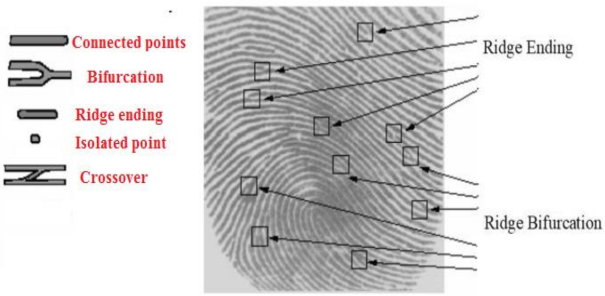


Figure 3. Minutiae used in this study.

These criteria must be addressed by the best FP features extraction technique, chosen on the basis of:

- Ease of use [20].
- Effectively reducing the time required to extract features [2].
- Not having duplicate features between FP images [1, 3, 9].
- Being non-sensitized to the angular position of an input picture [17, 21].
- The characteristics used to create an FP picture remaining constant over time [12, 18].

2. Related Works

Fingerprint identification has emerged as the most widely used biometric method in recent years [8]. However, the vertical orientation of FP stored in the database is not guaranteed and may be inaccurate by a little or a great deal [10]. In practice, it is challenging to work with fingerprints of low quality and to avoid being fooled by a bad structural signal caused by issues with the fingerprint itself, such as cracks or sweaty fingers [6]. Furthermore, rotating the fingerprint image can change the FP's features.

K-means clustering [8, 23] and Wavelet Packet Tree (WPT) decomposition [1, 2, 3, 5], alongside other approaches, can extract features from digital pictures, such as the fingerprinting [15, 16, 17, 23] using LBP- and granularity-based crossing number computation [1, 3, 11, 12 , 13, 17, 23]. Some of these techniques have drawbacks, such as:

- Producing a changeable number of features, which makes it difficult to use a features array with variable length.
- Sensitivity to image rotation, in which case the features will change if the FP image is rotated, necessitating the rotation to be treated as a new image, which requires additional memory and processing time.

For some characteristics, certain techniques produce unpredictable (random) values that can shift from one run to the next. In this case, the suggested approach will resolve such issues by counting the occurrences of certain shapes inside a picture, which can then be used as characteristics of the digital image. Finding a matching structural element in the image is the key to detecting any form in the image.

The location of the form in the image may be determined using a hit-and-miss operation applied to the chosen structuring element. Table 1 presents the main features of the existing used methods of FP image features extraction.

Table 1. Existing methods of features extraction properties.

Method	Simple to implement	Stability of the features	Fixed number of features	Sensitivity to FP image rotation	Remarks
K-means	Yes	No	Yes	Yes	It is difficult to set the initial values
WPT	Yes	Yes	No	No	Rotated image must be treated as another image and saved
LBP-based	Yes	Yes	Yes	No	Rotated image must be treated as another image and saved
Minutiae extraction	Extra efforts	Yes	Yes	Some times	A routine must be written to extract all minutiae

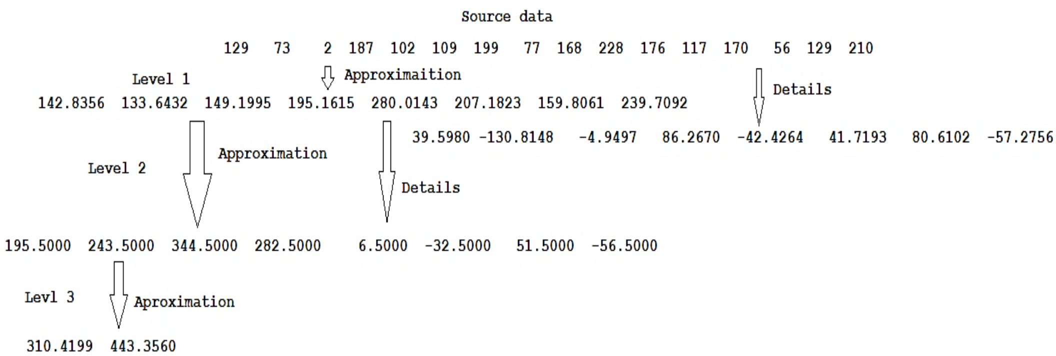


Figure 4. WPT decomposition.

By applying WPT decomposition, an input data set (reshaped to a single row fingerprint picture) is broken down into approximations and details. Haan equations are used, as shown illustrated in Figure 4. Here, the picture size needs to be a multiple of 2, so that we may choose the appropriate decomposition level to obtain the required constant approximation value set. The issue can be fixed by decreasing the picture size to a power of two. When using K-means clustering, the input dataset is divided into clusters, and the cluster centroids are then used to create a FP features vector. The centroids may have changed from one run to the next, and the time needed to compute them depends on the number of runs and the size of the FP; the approach is readily processed but takes time.

At the outset of K-means, there is an initialization stage in which we choose the number of clusters and the values of their centroids. The processing includes many passes, with each pass consisting of the following steps:

- Calculate the distance from each data point's centroid.
- Put the information into the right cluster based on how far apart they are
  - Calculate the mean of each group of data (in each cluster).
  - Replace the centered values with the mean values obtained from the calculations.
  - Run the algorithm again if there has been a shift in the centered points.

Clustering of data is presented in Tables 2, and 3.

Table 2. Data clustering example (pass 1).

Data set	D1	D2	Cluster	New centroids
172	72	22	2	C1=84.5 C2=181.333
178	78	28	2	
186	86	36	2	
122	22	28	1	
141	41	9	2	
31	69	119	1	
115	15	35	1	
183	83	33	2	
228	128	78	2	
70	30	80	1	

Table 3. Data clustering example (pass 2).

Data set	D1	D2	Cluster	New centroids
172	87.5000	9.3330	2	C1=84.5 C2=181.333
178	93.5000	3.3330	2	
186	101.5000	4.6670	2	
122	37.5000	59.3330	1	
141	56.5000	40.3330	2	
31	53.5000	150.3330	1	
115	30.5000	66.3330	1	
183	98.5000	1.6670	2	
228	143.5000	46.6670	2	
70	14.5000	111.3330	1	

3. The Proposed Method

In this section, we present the proposed method of enhancing FP detection, which is constantly subjected to detrimental factors such as finger perspiration and this in turn disrupts the connectivity of lines in the fingerprint [19]. The suggested technique begins with a FP image improvement to boost the image's pixel connectivity and texture quality. To obtain this improvement, just determine and implement the local binary pattern image using the Long baseline projection (LBP) [14, 19, 22]. Figure 5 displays an example of LBP image computation, and the improvements may be seen in the picture histogram by normalizing it. Figure 6 gives a computed example.

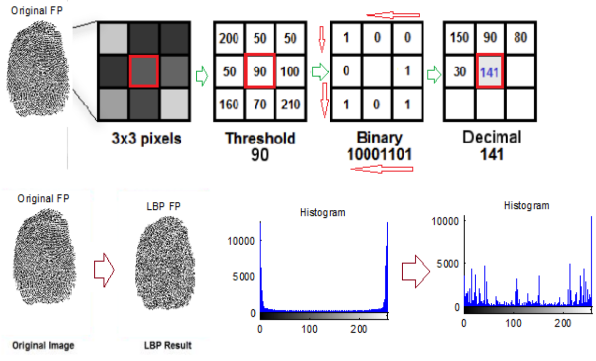


Figure 5. LBP image calculation.

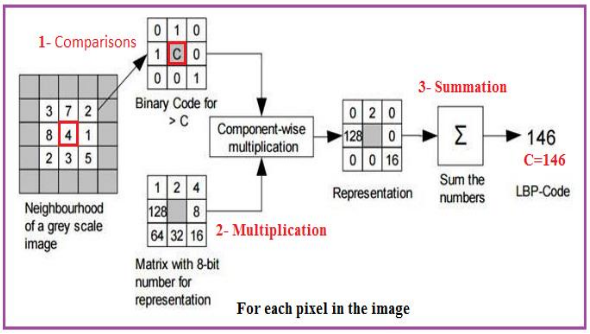


Figure 6. LBP image calculation (example).

The positive effects of using LBP image are shown in Table 4.

Table 4. Positive effects of using LBP image (enhanced).

FP #	Enhancement	Features				
		Bifurcation	Cross	Isolated points	Ridge ending	Connected points
1	yes	765	10	44	580	530
	N0	4	10	0	0	19
2	yes	7988	10	54	1201	10257
	N0	3	10	0	0	8
3	yes	283	10	16	112	164
	N0	2	10	0	0	40

The second step of the proposed method is applying a morphological hit-and-miss operation to detect each picture of the FP item. Identifying patterns of foreground and background pixels in an image requires the hit-and-miss transform, a generic binary morphological operation [16].

The Structuring Element (SE) may be used to do a hit-and-miss operation on the binary picture; if the SE matches the item we are searching for, we will obtain a 1 back in the center of that object, and the number of ones will indicate the total number of features in the image. Implementing hit-and-miss may be achieved by following these steps.

1) Obtain the binary representation of the FP picture (1).
2) Pick the standard error value SE that corresponds to your goal. These five locations are a bifurcation, a crossing, an isolated point, the end of a ridge, and a linked point.
3) To conclude (1), we use SE to eliminate (2).

4) Remove the result of replacing (a complement) with SE's complement (3).
5) the matrix is obtained by combining (2), (3) and (4).

The procedures outlined in steps 3-4 must be repeated for all the elements of the object structure shown in Figures 8, 9, 10, 11, and 12). (4) is added together in step 5 to form the final sum (steps 3-5 can be implemented using the Matlab function bwhitmiss. In Figure 7, we see the result of a hit-and-miss procedure applied to a single item; the number of 'ones' added up represents the total number of objects.

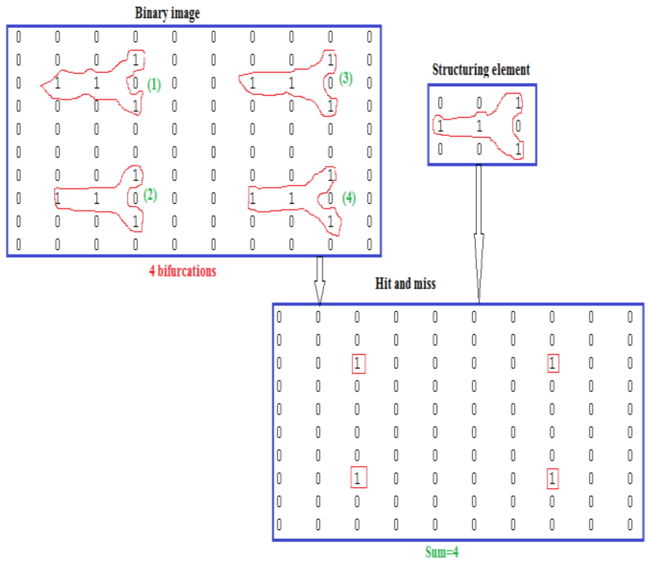


Figure 7. Hit-and-miss example.

One or more SE elements must be chosen and a hit-and-miss operation performed using each SE; moreover, the FP picture must be analyzed to determine how many objects there are. The resulting matrices are summated to obtain the number of objects in the FP image. Figures 8, 9, 10, 11, and 12 show SEs for each object.

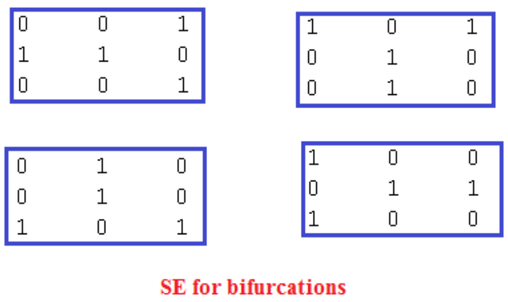


Figure 8. SEs for bifurcation.

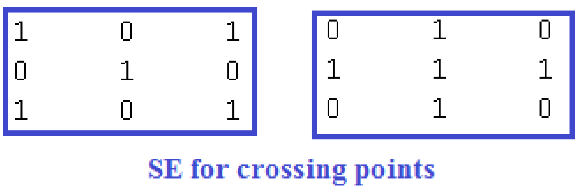


Figure 9. SEs for crossover.

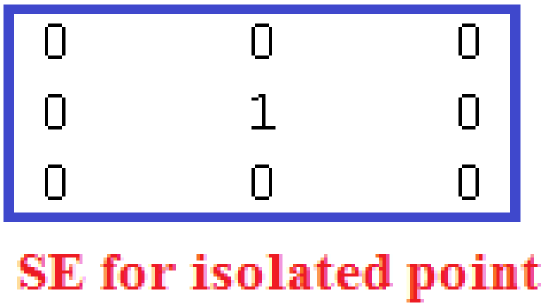


Figure 10. SE for isolated point.

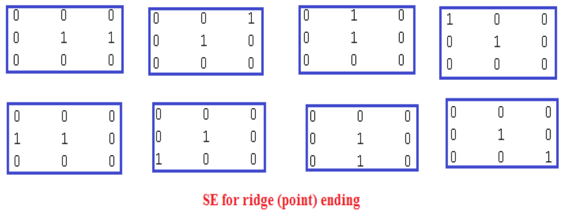


Figure 11. SEs for ridge ending.

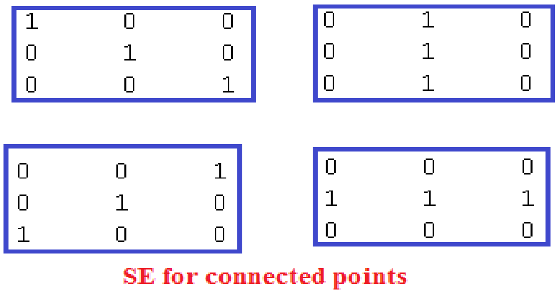
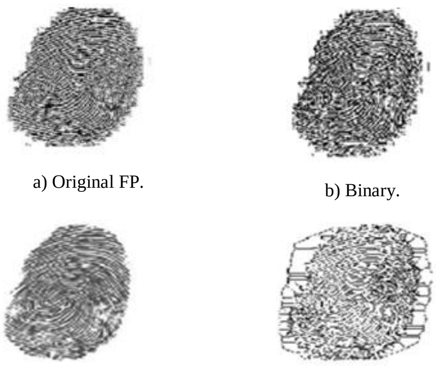


Figure 12. SEs for connected points.

4. Implementation and Experimental Results

Scanner "Digital Personal 4500 Fingerprint Reader" has been used capture the fingerprints, and they were stored as PNG images. The finger used to generate the fingerprints was dry and under normal conditions then the scanning process was carried out more than once and the clearest fingerprint was used. One hundred FP samples were taken from a random subset of students and then kept for later use as reference pictures in the suggested method's implementation. Rotations of varying degrees were applied to finger print 1(FP 1) to treat it and a representative example of the outcomes is shown in Figure 13; the resulting experimental data can be seen in Table 5. To improve the cohesiveness of the final product, a local binary pattern picture was computed for each FP. The resulting picture was then reduced using a morphological opening technique and converted to binary.



a) Original FP. b) Binary.

c) LBP. d) Thinned.

Figure 13. Sample FP outputs.

Table 5 shows that the FP characteristics are unaffected by picture rotation, demonstrating that the suggested technique is robust against FP rotation. Table 6 ignores crossover objects because they were equal zero and this table displays the outcomes of the experiments performed on the selected FP photos, including the detection and count of the various items included in each image. It reveals that each FP image has its own distinct set of object counts (features) that can be used to identify and categorize its owner, while Table 7 reveals that the number of crossover objects remains constant across all FP images. This means it can be ignored to accelerate the extraction process.

Table 5. Objects counts FP images.

Image	Bifurcation	Cross	Isolated points	Ridge ending	Connected points	Extraction time (sec)
FP 1	765	10	44	580	530	0.658000
FP 2	7988	10	54	1201	10257	3.209000
FP 3	283	10	16	112	164	0.371000
FP 4	215	10	8	86	141	0.270000
FP 5	140	10	2	79	104	0.255000
FP 6	734	10	77	772	634	0.555000
FP 7	6522	10	627	5098	4533	1.748000
FP 8	216	10	3	52	100	0.249000
FP 9	256	10	4	72	134	0.247000
FP 10	133	10	1	42	126	0.249000

Table 6. Samples of the finger prints show features after ignoring crossover objects.

Image	Bifurcation	Isolated points	Ridge ending	Connected points	Extraction time (sec)
FP 1	765	44	580	530	0.606000
FP 2	7988	54	1201	10257	2.914000
FP 3	283	16	112	164	0.335000
FP 4	215	8	86	141	0.227000
FP 5	140	2	79	104	0.235000
FP 6	734	77	772	634	0.492000
FP 7	6522	627	5098	4533	1.508000
FP 8	216	3	52	100	0.228000
FP 9	256	4	72	134	0.233000
FP 10	133	1	42	126	0.229000
Average					0.7007

The methods mentioned above were implemented using the same FP and Table 7 shows the average feature extraction time for these methods.

Table 7. Time comparisons.

Method	Average extraction time (sec)	Remarks
K-means clustering	1.079	4 clusters were selected
WPT decomposition	1.925	FP size must be resized to a multiple of 2
LBP-based method	0.012	Not sensitive to FP rotation. Each rotated FP will have new features
Minutiae	0.968	Requires FP binarization and thinning

Comparisons were made in depth in [22], as shown in Table 7. Except for the LBP-based method, which has the highest performance but is susceptible to FP rotation, the suggested methodology outperforms these other approaches. The proposed method was accurate; the accuracy of the method was determined by the extracted fingerprints; each fingerprint was a unique.

5. Conclusions

The suggested and implemented method for fingerprint images is straightforward. Although this approach takes somewhat longer than others, it is particularly cost-effective since the memory required to store the various FP models is considerably reduced due to the FP image's potential for rotation. The experiments demonstrated that item counts may be used to create FP picture characteristics that are specific to each FP image. The suggested approach is unaffected by the angle at which a picture is rotated, and therefore a single features array may be generated for all photos that have been rotated. Using the suggested approach, you can select the desired SE and then count any item present in the FP picture.

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