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RESEARCH ARTICLE

Detecting and Counting Minutiae in Human Fingerprint

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Abstract:

Human fingerprint is unique to every person and can be used easily for identification purposes. People leave fingerprints almost everywhere and that's why using fingerprint databases for investigation is so common. Fingerprints can be used in many important and vital applications: providing vital security, and sometimes fingerprint may be distorted (deformed) because it was taken from somewhere where the place was wood plank, wall or door hand, so we need to enhance the image, in this paper we will introduce LBP enhancement for better minutiae detection and counting, and it will be showed how to construct a fingerprint identifier (features) to be used later as a key to retrieve or recognize the fingerprint..

Keywords: Histogram, LBP, fingerprint, minutiae, ridge ending, bifurcation, Euclidian distant

Introduction

From the beginning of time to the current present day, data security systems have been a matter of interest and concern to everyone looking to protect vital and important data. Walls, gates, and watchtowers were some of the safety system used at that time and these days are still to secure our home, office, or workplace that required security from an unwanted hacker [1], [2]. These secure and safety systems have changed by the time, and they guarantee the latest technology to make this safety safer. Advanced safety and classic safety are always the same [3], [4].

Human fingerprint is unique to every person and can be used easily for identification purposes. People leave fingerprints almost everywhere and that's why using fingerprint databases for investigation is so common. Fingerprints can

be used in many important and vital applications: providing vital security (for example, controlling access to areas or safe systems) ... conducting background checks (including government job applications, defensive security clearance, hidden weapons permits, etc.).

Fingerprint, papillary impression on the fingerprint ridges tips and thumb which are called minutiae. Fingerprints provide an impeccable way to personal identity, because minutiae arrangement on each finger of every human being is unique and does not change with growth or age.

Fingerprint image can be represented by a 2D matrix (for gray fingerprint image), or by a 3d matrix (for a color fingerprint image), the capture fingerprint image is subjective to some preprocessing operations such as:

- Image enhancement.
- Image thinning.
- Converting image to binary image.

Fingerprint structure

Human fingerprint image contains several unique objects each of them is called minutiae as shown in figure 1, the number and types and the locations of these objects are differ from one person to another [5].

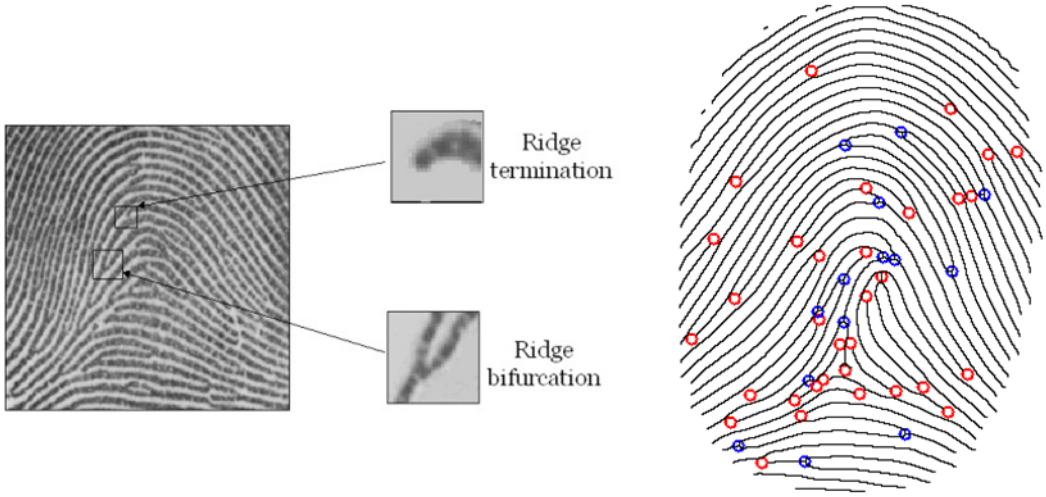

Figure 1: Fingerprint structure

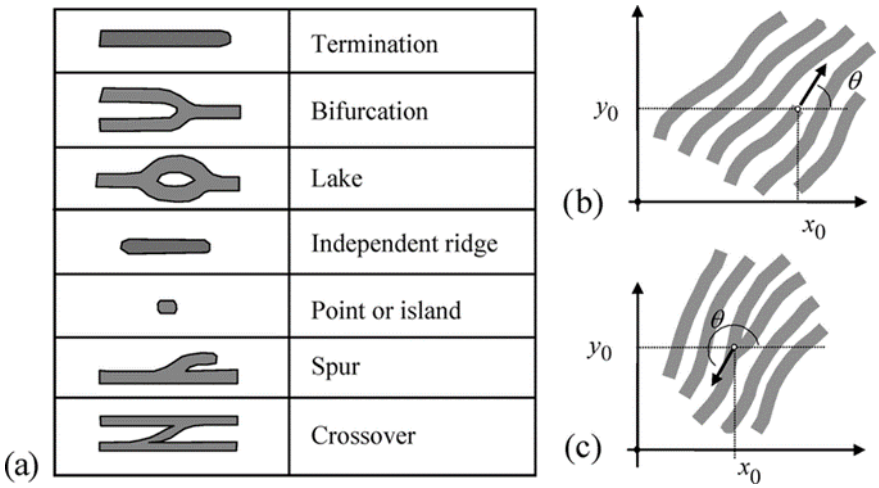

Figure 2: a) Minutiae types
b) Coordinates
c) Orientation

Each minutiae in the fingerprint image can be easily detected depending on the 8 neighbors values and using the calculated classifier number (CN) as shown in figure 3 [3], [4], [5]:

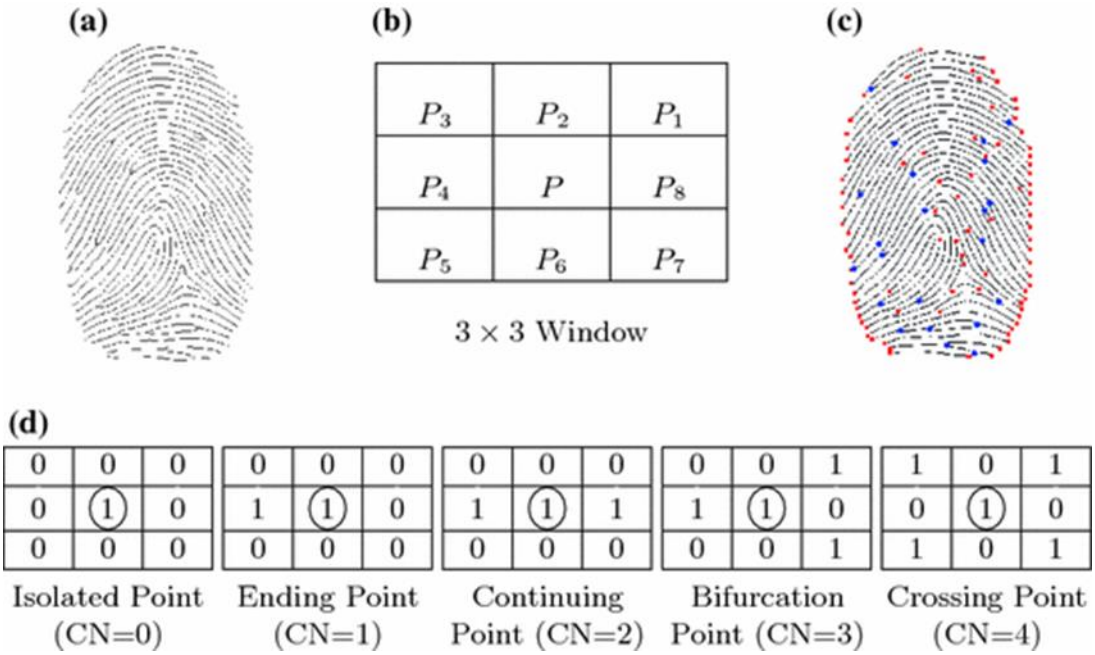

Figure 3: CN for various types of minutiae

Fingerprint enhancement using histogram equalization

For better minutiae detection we need to enhance the fingerprint image, one of the popular methods used for image enhancement is histogram equalization [6], [7].

Image histogram is a one column array of 256 elements, each element value points to the repetition of a gray value (0 to 255) [8], [9], [10], the histogram may

give us a true picture about the image, if the contents of histogram are normally distributed, then the image is clear, otherwise it requires equalization, and to do this we have to follow the following steps [11], [12]:

Step 1: for images with discrete gray values, compute(formulas 1 and 2)[23], [24]:

$$P_{in}(r_k) = \frac{n_k}{n} \quad , 0 \le r_k \le 1, \ 0 \le k \le L-1 \tag{1}$$

L: Total number of gray levels

n_k: Number of pixels with gray value r_k

n: Total number of pixels in the image

Step 2: Based on CDF, compute the discrete version of the previous transformation:

$$S_k = T(r_k) = \sum_{j=0}^{k} P_{in}(r_j) \quad , \quad 0 \le k \le L-1 \tag{2}$$

Table 1 shows an example of histogram equalization (here for simplicity we use a maximum gray value of 7)[13-16].

Table 1: Example of histogram equalization

Gray level(r_k)	No. of Pixels(n_k)	PDF(n_k/N) $P_r(r_k)$	CDF	(L-1)*CDF	H_k
0	8	0.13	0.13	0.91	1
1	10	0.16	0.29	2.03	2
2	10	0.16	0.45	3.15	3
3	2	0.03	0.48	3.36	3
4	12	0.18	0.66	4.62	5
5	16	0.25	0.91	6.37	6
6	4	0.06	0.97	6.79	7
7	2	0.03	1.0	7	7
	64	1			

Here 0 will become 1, 1 well become 2 and so on.

Sometime the histogram equalization fails when the fingerprint image has a large area of low-intensity background. In this case, the histogram will have a spike component corresponding to the background gray level. After histogram

equalization, the output image will have a severe washed-out appearance while its dynamic range actually becomes smaller (see figure 4).

Considering the disadvantages of histogram equalization, we can use a LBP histogram method to enhance the fingerprint image[21], [22].

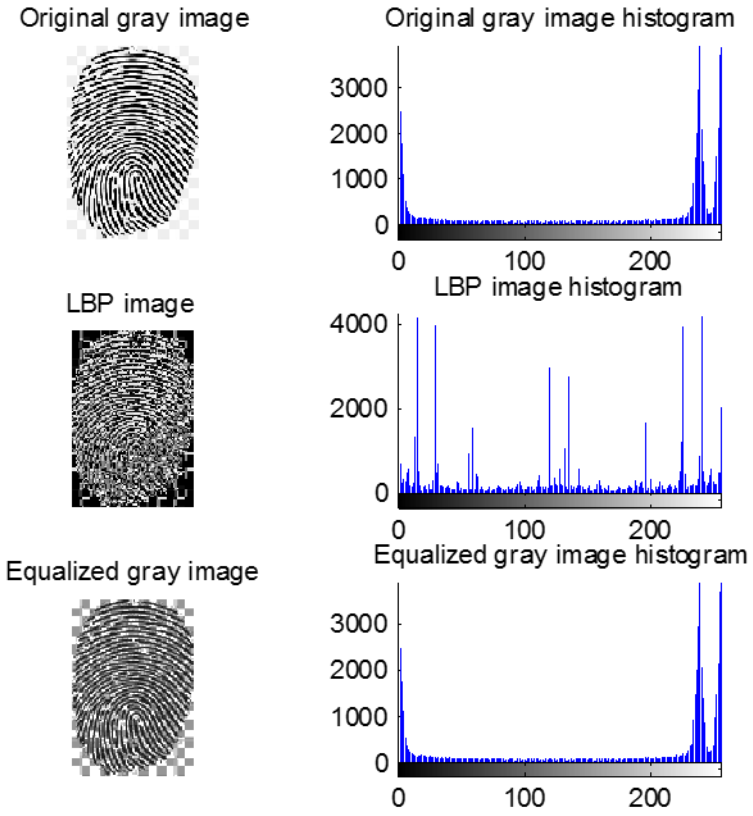

Figure 4: Equalized and LBP histograms

Creating LBP histogram

Local binary pattern (LBP) histogram of the fingerprint image is a histogram of an output image after applying LBP operator calculations for each pixel in the input image [17], [18].

LBP image [19] can be obtained applying the steps shown in figure 5, the resulting image then will be used as an input image for fingerprint minutiae detection, this will give us a better enhancement, and this will be reflected in the accuracy of the process of detecting and counting minutiae in the fingerprints[25], [26], figure 6 show a sample example of new image pixel calculation based on LBP method:

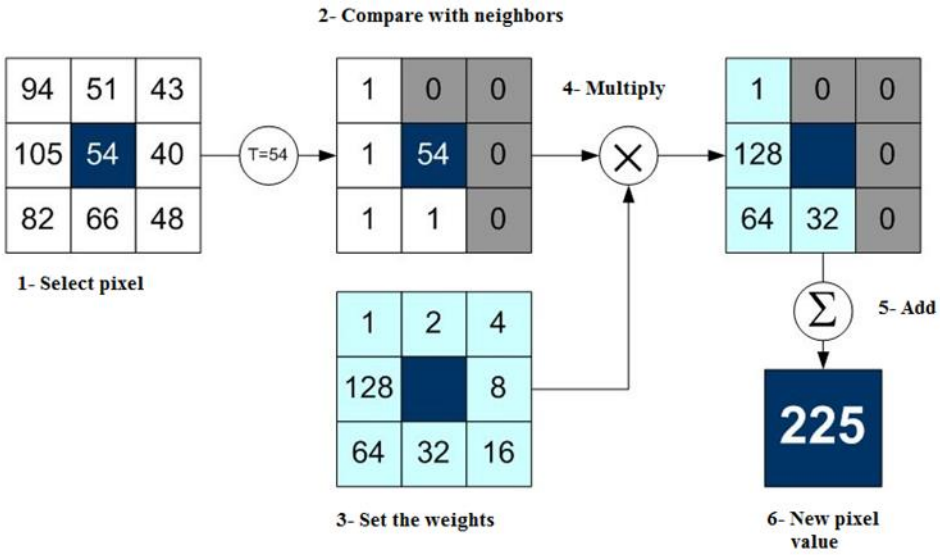

Figure 5: LBP calculation

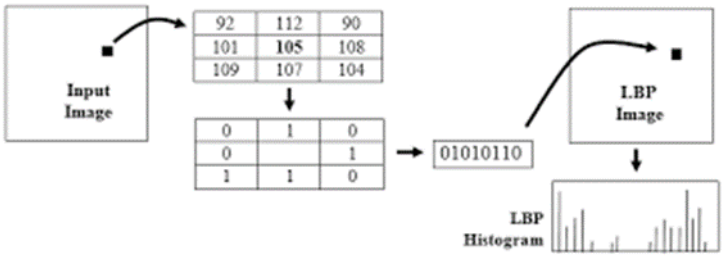

Figure 6: Example of calculating LBP pixel

Implementation and experimental results

To detect and count the minutiae in the human fingerprint, we have to apply the following steps(see figure 7):

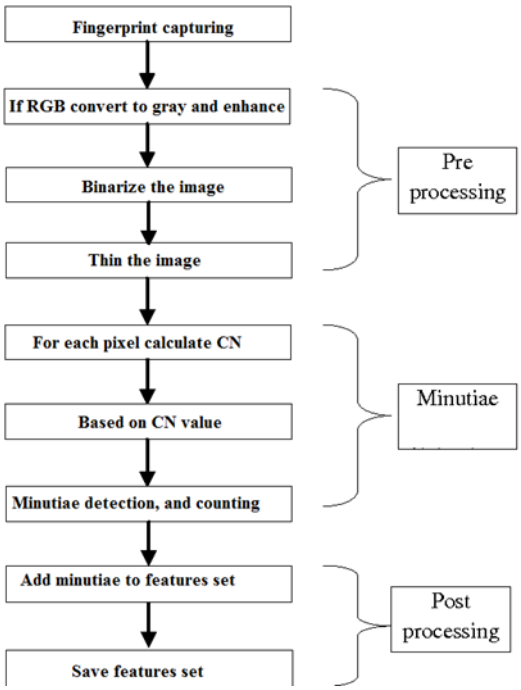

Figure 7: Minutiae counting and detecting flowchart

1) Fingerprint capturing.
2) If the fingerprint is color, then convert the color image to gray one.
3) The fingerprint may be distorted (deformed) because it was taken from somewhere where the place was wood plank, wall or door hand, so we need to enhance the image, and here we recommend using LBP enhancement because of the reasons mentioned previously, and the reasons that will be discussed from the obtained experimental results later.
4) Convert the enhanced image to binary image.
5) Apply image thinning using morphological thin operation.
6) For each pixel in the thinned binary image do the following:
    a) Calculate CN.
    b) Add 1 to the type of minutiae denoted by CN value.
    c) Save the minutiae coordinates.
    d) Save the minutiae orientation angle.

These steps were implemented using matlab, several fingerprints were taken and below we will show the experiment results.

Although the first method of image enhancement (histogram equalization) takes less time, we recommend that you use the second method (LBP equalization) for the aforementioned reasons (see table 2).

Table 2: Enhancement time

Fingerprint	Size (pixel)	LBP time(s)	Histogram equalization time(s)
1	3556800	0.1080	0.0370
2	50625	0.0050	0.0330
3	296400	0.0100	0.0330
4	3878400	0.2700	0.0450
5	90000	0.0080	0.0320
6	3747900	0.1080	0.0360
7	151200	0.0040	0.0320
8	4757340	0.1060	0.0380
9	3878400	0.2740	0.0460
10	3292596	0.4950	0.0450
11	4164000	0.1010	0.0380
12	262144	0.0190	0.0350
13	153450	0.0040	0.0330
14	5760000	0.4050	0.0550
Average	2431400	0.1369	0.0384

Experiment 1: Detecting minutiae using the whole fingerprint image

a) Without image enhancement

Several fingerprints were selected, a matlab code was written and implemented, and table4 shows the results of detecting the number of minutiae and the counts for the most appearing in the image minutiae:

Table 4: Experiment 1 a) results

Fingerprint	Size	Isolated points	Ridge ending	Continuing point	Bifurcation	Number of various minutiae
1	3556800	12	192	49795	2615	9
2	50625	0	0	0	0	0
3	296400	0	11	7380	343	5
4	3878400	0	172	57484	696	5
5	90000	0	42	7593	302	5
6	3747900	0	127	41803	1302	8
7	151200	1	156	6207	752	7
8	4757340	0	168	46849	528	5
9	3878400	0	7172	101339	21203	7
10	3292596	1	219	77182	1505	5
11	4164000	2	157	28708	187	5
12	262144	0	0	0	0	0
13	153450	0	0	0	0	0
14	5760000	1	338	44590	432	5

From table 4 we can see the following facts:

- The process of minutiae detection was failed for some fingerprints (red results: images 2, 12 and 13).
- Each row in table 4 (Isolated points, Ridge ending, Continuing point, Bifurcation, and Number of various minutiae) is not a unique, so we

cannot use each of them as a features (identifier) to retrieve or recognize the fingerprint, and this will lead us to seek a better method, one of these methods is to enhanced LBP fingerprint image.

b)With image enhancement(LBP histogram)

Several fingerprints were selected, a matlab code was written and implemented, and table 5 shows the results of detecting the number of minutiae and the counts for the most appearing in the image minutiae:

Table 5: Experiment 1 b) results

Fingerprint	Size	Isolated points	Ridge ending	Continuing point	Bifurcation	Number of various minutiae
1	3556800	2279	30163	113450	63682	9
2	50625	204	1405	3732	944	6
3	296400	741	3468	8032	5563	8
4	3878400	3	610	47207	8	5
5	90000	246	1468	9800	2953	7
6	3747900	1975	29449	105800	58488	9
7	151200	29	546	5400	1515	7
8	4757340	1637	3673	47135	2330	6
9	3878400	4582	4516	44707	4372	6
10	3292596	9	1728	61788	35	5
11	4164000	18650	30914	33121	6485	5
12	262144	1369	6145	13097	3088	8
13	153450	47	134	204	0	3
14	5760000	4	642	45126	6	5
		Features (Identifier)				

From table 5 we can see the following facts:

- The process of minutiae detection was succeeded for all fingerprints (green results).
- Each row in table 5 (Isolated points, Ridge ending, Continuing point, Bifurcation, and Number of various minutiae) is a unique, so we can use each of them as a features (identifier) to retrieve or recognize the fingerprint.
- LBP histogram equalized image method can be recommended as an input image for fingerprints minutiae counting and detection.

c)With histogram equalization enhancement

Several fingerprints were selected, a matlab code was written and implemented, and table 6 shows the results of detecting the number of minutiae and the counts for the most appearing in the image minutiae:

Table 6: Experiment 1 c) results

Fingerprint	Size	Isolated points	Ridge ending	Continuing point	Bifurcation	Number of various minutiae
1	3556800	1360	15668	94482	50940	9
2	50625	1	0	0	0	1
3	296400	4	222	6303	3320	9
4	3878400	0	174	57541	648	5
5	90000	11	286	9876	2317	8
6	3747900	4365	25785	67535	15397	8
7	151200	285	1040	3139	779	7
8	4757340	0	172	48261	6306	8
9	3878400	0	2	783	0	3
10	3292596	4	226	77001	1453	5
11	4164000	0	2	387	0	3
12	262144	1	0	0	0	1
13	153450	0	2	88	0	3
14	5760000	1	0	0	0	1

From table 6 we can see the following facts:

- The process of minutiae detection was failed for some fingerprints (red results: images 2, 12 and 14).
- Each row in table 6 (Isolated points, Ridge ending, Continuing point, Bifurcation, and Number of various minutiae) is not a unique, so we cannot use each of them as a features (identifier) to retrieve or recognize the fingerprint, and this will lead us to use LBP fingerprint image.

Experiment 2: Using a segment from the fingerprint

To reduce the minutiae detection and extraction time we can use a selected segment with a smaller size from the fingerprint, this segment can be used as an input image to detect and count minutiae.

a)Without image enhancement

Several fingerprints were selected, a segment from the image was defined, a matlab code was written and implemented, and table 7 shows the results of detecting the number of minutiae and the counts for the most appearing in the image minutiae:

Table 7: Experiment 2 a) results

Finger print	Size	Used size	Isolated points	Ridge ending	Continuing point	Bifurcation	Number of various minutiae	Extraction time
1	3556800	974400	12	145	37167	1540	5	1.1470
2	50625	15625	0	0	0	0	0	0.0240
3	296400	44800	0	3	3445	185	5	0.0630
4	3878400	3486800	0	171	52676	612	5	3.8640
5	90000	40000	0	21	3251	83	5	0.0560
6	3747900	1033200	0	81	30789	308	6	1.1810
7	151200	15500	0	29	1348	138	6	0.0300
8	4757340	1334880	0	157	44536	474	5	1.5300
9	3878400	3486800	0	6865	97439	20369	7	4.2890
10	3292596	2928596	1	212	70552	1261	5	3.3400
11	4164000	1159200	2	134	25135	151	5	1.2980
12	262144	169744	0	0	0	0	0	0.1910
13	153450	15050	0	0	0	0	0	0.0240
14	5760000	5290000	1	338	44590	432	5	5.9110

From table 7 we can see the following facts:

- The process of minutiae detection was failed for some fingerprints (red results: images 2, 12 and 13).
- Each row in table 4 (Isolated points, Ridge ending, Continuing point, Bifurcation, and Number of various minutiae) is not a unique, so we cannot use each of them as a features (identifier) to retrieve or recognize the fingerprint, and this will lead us to seek a better method, one of these methods is to enhanced LBP fingerprint image.

b) With image enhancement(LBP histogram)

Several fingerprints segments were selected, a matlab code was written and implemented, and table 8 shows the results of detecting the number of minutiae and the counts for the most appearing in the image minutiae:

From table 8 we can see the following facts:

- The process of minutiae detection was succeeded for all fingerprints (green results).
- Each row in table 5 (Isolated points, Ridge ending, Continuing point, Bifurcation, and Number of various minutiae) is a unique, so we can use each of them as a features (identifier) to retrieve or recognize the fingerprint.
- LBP histogram equalized image method can be recommended as an input image for fingerprints minutiae counting and detection.

Table 8: Experiment 2 b) results

Finger print	Size	Used size	Isolated points	Ridge ending	Continuing point	Bifurcation	Number of various minutiae	Extraction time
1	3556800	974400	2031	26175	99007	59284	9	1.1470
2	50625	15625	10	234	1037	523	6	0.0240
3	296400	44800	231	1122	3357	2288	8	0.0630
4	3878400	3486800	3	574	45290	8	5	3.8640
5	90000	40000	90	617	4027	1308	6	0.0560
6	3747900	1033200	1807	26393	92533	55266	9	1.1810
7	151200	15500	8	72	1097	255	6	0.0300
8	4757340	1334880	1580	3589	44424	2248	6	1.5300
9	3878400	3486800	4392	4302	42178	4150	6	4.2890
10	3292596	2928596	6	1533	59623	32	5	3.3400
11	4164000	1159200	16580	27414	29115	5754	5	1.2980
12	262144	169744	1235	5291	10902	2440	8	0.1910
13	153450	15050	28	49	81	0	3	0.0240
14	5760000	5290000	4	642	45091	6	5	5.9110
			Features (Identifier)					

c) With histogram equalization enhancement

Several fingerprints segments were selected, a matlab code was written and implemented, and table 9 shows the results of detecting the number of minutiae and the counts for the most appearing in the image minutiae:

Table 9: Experiment 2 c) results

Finger print	Size	Used size	Isolated points	Ridge ending	Continuing point	Bifurcation	Number of various minutiae	Extraction time
1	3556800	974400	1240	14508	72827	43347	9	1.1470
2	50625	15625	1	0	0	0	1	0.0240
3	296400	44800	2	124	2847	1406	9	0.0630
4	3878400	3486800	0	173	52722	572	5	3.8640
5	90000	40000	3	102	3923	982	8	0.0560
6	3747900	1033200	4063	23664	50671	11795	8	1.1810
7	151200	15500	94	205	613	146	7	0.0300
8	4757340	1334880	0	159	45784	6050	8	1.5300
9	3878400	3486800	0	2	783	0	3	4.2890
10	3292596	2928596	4	219	70387	1229	5	3.3400
11	4164000	1159200	0	2	387	0	3	1.2980
12	262144	169744	1	0	0	0	1	0.1910
13	153450	15050	0	0	0	0	0	0.0240
14	5760000	5290000	0	0	0	0	0	5.9110

From table 9 we can see the following facts:

- The process of minutiae detection was failed for some fingerprints (red results: images 2, 12 13 and 14).

- Each row in table 4 (Isolated points, Ridge ending, Continuing point, Bifurcation, and Number of various minutiae) is not a unique, so we cannot use each of them as a features (identifier) to retrieve or recognize the fingerprint, and this will lead us to seek a better method, one of these methods is to enhanced LBP fingerprint image.

As we said earlier in this paper, each fingerprint contains a unique number of minutiae and a unique count of each of them, so it is suitable to use them as a fingerprint identifier.

From the above obtained results we can see that ridge ending and bifurcation minutiae have the most bigger counts, so we can focus on the to use them as a fingerprint identifier, by adding the Euclidian distant between coordinates [20] , these parameters are fixed for each fingerprint, thus we can easily use them as a fingerprint features, table 10 shows the features for the fingerprint 1, by taking a 100 by 100 pixels segment.

Table 10: Fingerprint 1) segment 100 by 100) features

Ridge ending(137 points)			Bifurcation(247 points)		
X-coordinates(first 10 points)	Y-coordinates(first 10 points)	Euclidian distant	X-coordinates(first 10 points)	Y-coordinates(first 10 points)	Euclidian distant
82	23	86.3134	87	24	87
86	23		86	26	
81	31		86	27	
71	32		87	27	
90	32		79	30	
82	38		84	34	
63	39		84	35	
67	39		87	36	
76	40		73	37	
82	40		74	37	

Conclusion

Several methods of preparing a fingerprint as an input image to detect and count minutiae, histogram equalization gave better performance with a speedup of 3.5651 times comparing with LBP method(0.1369/0.0384), but he base method to be used is an LBP based histogram equalization, because some time using histogram equalization will lead to fault fingerprint features.

From the obtained results we can conclude the following:

- Each fingerprint has a fixed number of deferent types of minutiae.
- The counts of minutiae are fixed for each fingerprint and are unique.
- We can use a segment from the fingerprint to detect and count minutiae, this will reduce minutiae extraction time,

For each fingerprint we can form the features (identifier) of each fingerprint by using ridge ending minutiae and bifurcation minutiae plus the coordinates Euclidian distant

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