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Analysis of Fingerprint Minutiae to Form Fingerprint Identifier

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***Abstract*— Detailed human fingerprints, almost unique, are difficult to change and are permanent on an individual's life, making them suitable as long-term signs of human identity. They may be employed by the police or other authorities to identify individuals who wish to conceal their identity, or identify incapacitated or deceased persons and therefore cannot identify them, as in the aftermath of a natural disaster. Fingerprints images are very important data type due to wide applications requiring this type, so extraction a fingerprint identifier is a vital issue. In this paper we will analyse the fingerprints images in order to extract minutiae from the images, these minutiae will be used to construct the fingerprint identifier, the proposed procedure will be implemented and tested to ensure that the procedure generates a simple and unique identifier, which can be easily used to recognize the fingerprint in any recognition system.**

***Keywords*— Fingerprint, digital image, minutiae, ridge ending, bifurcation, identifier, Euclidean distance.**

I. Introduction

The human fingerprint is the impression left by the friction of the human finger. Recovering partial fingerprints from the crime scene is an important method of forensic science. The moisture and grease in the finger causes fingerprints on surfaces such as glass or metal. Deliberate impressions of entire fingerprints can be obtained by ink or other materials transferred from the tops of friction edges on the skin to a smooth surface such as paper. Fingerprint records typically contain impres-sions from the panel on the last joint of the fingers and thumbs, although fingerprint cards usually record parts of the areas of the lower finger joint [1], [2].

Detailed human fingerprints, almost unique, are difficult to change and are permanent on an individual's life, making them suitable as long-term signs of human identity. They may be employed by the police or other authorities to identify individuals who wish to conceal their identity, or identify incapacitated or de-ceased persons and therefore cannot identify them, as in the aftermath of a natural disaster [3], [4].

Human fingerprints [5] are treated as digital gray images [23-40] or as a digital color imag-es [6], [7], [8], [23-40], each image as shown in figure 1 is represented by 2D matrix(for gray or binary fingerprint), or 3D matrix (for color fingerprint), the intersection of each row and column is called a pixel, and its value represent the color intensity (usually the value ranges from 0 to 255 for each color for the gray and the color images, or from 0 to 1 for the binary images) [10], [11].

Fig. 1 Fingerprint sample image

One of the most important processes involved in many vital applications is fingerprint identification in order to identify the person where this process requires high speed and accuracy. The fingerprint image size is very high, because the resolution of the image is significantly high; this will make it difficult to identify the fingerprint [12], [13].

To simplify the process of fingerprint identification and make efficient and accurate, we have to represent the fingerprint by a small in size array of features[21[, [22], which can be easily used in the process of identification [14], [15], [16]. Many methods were used to extract image features to be used as an identifier [17], [18], the extracted features must be characterized with the following:

- Simplicity of extraction.
- Minimum time of extraction.
- The features for each image must be unique to maximize the identification system accuracy.
- Must have a small size to reduce the needed memory space.

In this paper we will analyze and discuss the minutiae method of features extraction, concentrating our attention on ridge ending and bifurcations.

II. FINGERPRINT CHARACTERISTICS

Human fingerprint has a unique structure, and each fingerprint is composed of various objects, the repetition of each object, and the continents of each object are unique and differ from one person to another, so we can based on these objects to create a unique identifier for each fingerprint[1], [2].

Each fingerprint consists of a set of minutiae, minutiae has different shapes as shown in figure 2, these shapes can be considered as an objects which we have to detect in order to build a fingerprint identifier.

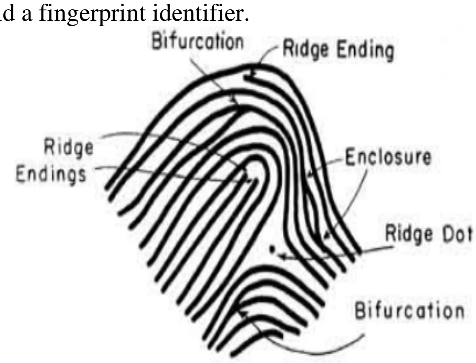

Fig. 2 Minutiae types

Figure 3 shows the most popular used minutiae in a human fingerprint.

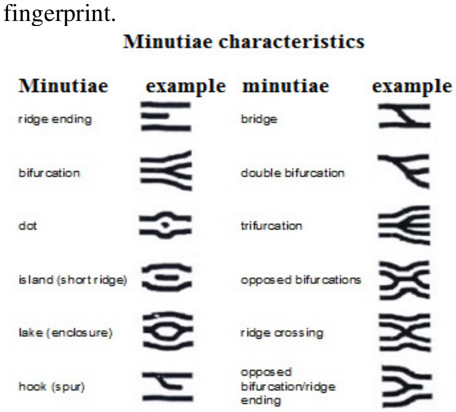

Fig. 3 Popular used minutiae

To detect and extract any minutiae we have to follow the following steps:

- Define a 3 by 3 mask, which we will call a classifier number (CN), this mask will be anded with each pixel and its neighbors, the sum of ones in the result will point to CN as shown in figure 4.

P_4	P_3	P_2
P_5	P	P_1
P_6	P_7	P_8

$$CN = \frac{1}{2}\sum_{i=1}^{8}|P_i - P_{i+1}|$$

Fig. 4 Calculating CN

- Each type of minutiae requires a special mask as shown in figure 5.

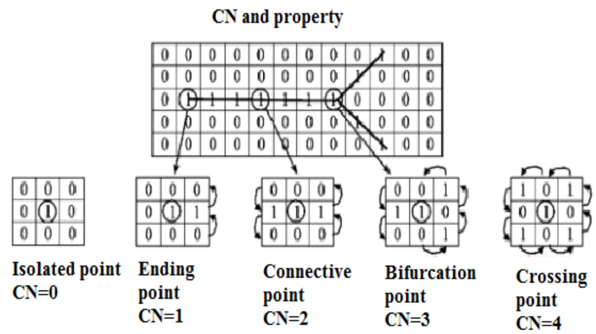

Fig. 5 Minutiae masks

- Applying anding will generate a matrix containing calculated CN values.
- Referring to the calculated matrix we can extract the points of various minutiae, and the number of points.

III. PROCEDURAL ANALYSIS OF MINUTIAE EXTRACTION

The procedural analysis required to extract various fingerprint minutiae can be performed as shown in figure 6 applying the following steps:

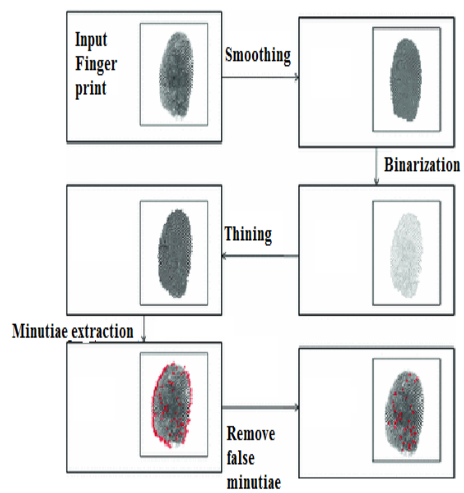

Fig. 6 Steps to extract minutiae

1) Get the image of the fingerprint.
2) If the image is color, convert it to gray.
3) Convert the gray image to binary.
4) Smooth the image; apply image thinning based on morphological operations [19].
5) Extract the selected types of minutiae applying the previous mentioned procedures.
6) Remove false minutiae.

To minimize the number of points in each minutiae and the extraction time, we can take a take a selected segment of the image with smaller size (for example 100x100 pixels).

Figure 7 shows an example of thinned image and the extracted minutiae.

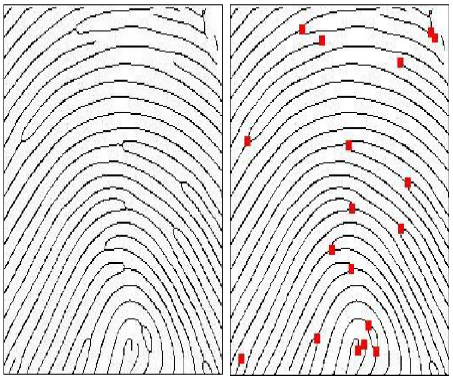

Fig. 7 Example of extracted minutiae

IV. Implementation And Experimental Results

The proposed procedures were implemented using matlab, figure 8, 9, and 10 show the output examples of the executed matlab code:

Fig. 8 Original fingerprint image

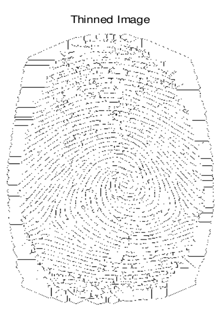

Fig. 9 Thinned image

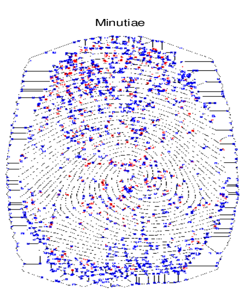

Fig. 10 Extracted minutiae

Taking the thinned original image as an input to detect and extract minutiae will lead to extracting minutiae with large number of points, thus the size of the obtained minutiae will be large and the extraction time will be also big, figure 11 shows some samples of treated fingerprint, while table 1 shows the extracted minutiae:

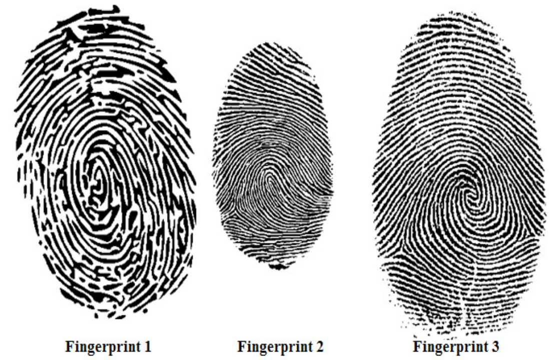

Fig. 11: Samples of treated fingerprint

TABLE 1
EXTRACTED MINUTIAE FOR FIGURE 3 SAMPLES

Characteristic	Number of points(Finger print 1)	Number of points(Fingerp rint 2)	Number of points(Finger print 3)
Isolated points	0	0	81
Ridge ending point	**172**	**168**	**58**
Connective point	57484	46849	40656
Bifurcation point	**696**	**528**	**3015**
Crossing point	49	66	440

In this paper research we will focus only on ridge ending and bifurcation types of minutiae, they are sufficient to create a unique identifier for a fingerprint, as will be shown later in this part.

Table 2 shows the first 10 points coordinates of the ridge ending minutiae, while table 3 shows the first 12 points coordinates of bifurcation of the first sample of finger print:

TABLE 2
RIDGE ENDING POINTS

Ridge ending	Ridge_x	Ridge_y
1	74	12
2	41	17
3	40	19
4	39	21
5	70	21
6	69	23
7	92	24

8	91	26
9	36	28
10	90	28

TABLE 3
BIFURCATIONS POINTS

Bifurcation	Bifurcation_x	Bifurcation_y
1	76	12
2	77	12
3	84	12
4	86	14
5	29	15
6	39	17
7	38	19
8	92	21
9	20	22
10	71	22
11	84	22
12	20	23

Different fingerprints with different sizes were implemented to extract ridges ending and bifurcations points, table 4 shows the results of this implementation:

TABLE 4
MINUTIAE FOR DIFFERENT FINGERPRINTS

Finger print	Resolution (pixel)	Size (byte)	Number of ridge ending	Size (byte)	Number of bifurcations	Size (byte)	Extraction time(s)
1	1133 x 784	888272	581	9296	3015	48240	1.104000
2	964 x1645 x3	4757340	168	2688	528	8448	1.828000
3	2400x 1616	3878400	7172	114752	21203	339248	4.900000
4	2322x 1418	3292596	219	3504	1505	24080	3.808000
5	1388x 1000x 3	4164000	157	2512	187	2992	1.631000
6	2400x 2400	5760000	338	5408	432	6912	6.445000
7	1300x 912x3	3556800	192	3072	2615	41840	1.471000
8	1300x 961x3	3747900	127	2032	1253	20048	1.524000
9	2400x 1616	3878400	172	2752	696	11136	4.424000
Average							3.0150

From table 4 we can see that average extraction time is significantly high, also the number of points in each minutiae is also big, which leads to a huge number of extracted points.

The minimize the negative effects of the above mentioned disadvantages, we can use a selected segment of the fingerprint with a small fixed size, table 5 shows the extracted minutiae for the above used fingerprints with a 100x100 pixel segment

TABLE 5
MINUTIAE FOR DIFFERENT FINGERPRINTS USING SMALL SEGMENT

Finger print	Segment resolution	Size (byte)	Number of ridge ending	Size (byte)	Number of bifurcations	Size (byte)	Extraction time(s)
1	100*100	10000	2	32	7	112	0.028000
2	100*100	10000	1	16	17	272	0.023000
3	100*100	10000	32	512	79	1264	0.022000
4	100*100	10000	4	64	12	192	0.02760
5	100*100	10000	5	16	13	48	0.023000
6	100*100	10000	1	16	3	48	0.020000
7	100*100	10000	1	16	22	352	0.021000
8	100*100	10000	5	80	9	144	0.023000
9	100*100	10000					0.024000
Average							0.0235

From table 5 we can see the following facts:

- The extraction time was significantly reduced.
- The number of points in each minutia also was reduced, reducing the memory space required to store the points.
- The number of points for each finger print is unique.
- The points coordinate values for each minutia are also unique.

To minimize the size of the fingerprint identifier size we can form the identifier from the following components:

- Number of points in the ridge ending minutiae.
- Euclidean *distance* of the ridge ending point[20] which can be calculated applying the following formula:

$$d(\mathbf{p},\mathbf{q}) = d(\mathbf{q},\mathbf{p}) = \sqrt{(q_1-p_1)^2 + (q_2-p_2)^2 + \cdots + (q_n-p_n)^2}$$

$$= \sqrt{\sum_{i=1}^{n}(q_i-p_i)^2}.$$

  Where p and q are the points coordinates.
- Number of points in the bifurcation.
- Euclidean *distance* of bifurcation points.

Table 6 shows the extracted and the calculated components of fingerprint identifiers:

TABLE 6
EXTRACTED AND THE CALCULATED COMPONENTS OF FINGERPRINT IDENTIFIERS

Finger print	Fingerprint identifier (Features)			
	Number of ridge ending	Euclidean *distance* ridge ending	Number of bifurcations	Euclidean *distance* bifurcation
1	**2**	**31.3847**	**7**	**19.1050**
2	**1**	**4**	**17**	**2.2361**
3	**32**	**66.4831**	**79**	**91.2195**
4	**4**	**144**	**12**	**47.4236**
5	**5**	**19.3518**	**13**	**29.2634**
6	**1**	**196**	**3**	**48.7955**
7	**1**	**25**	**22**	**84.1487**
8	**5**	**11.6581**	**9**	**21.3327**
9	**11**	**17.9705**	**23**	**21.0246**

V. CONCLUSIONS

A simple, accurate and efficient procedure for fingerprint identifier extraction was proposed, tested and implemented. The obtained exper-imental showed the following facts:

- The procedure requires small amount of time to extract minutiae.
- The memory space required is small.
- It is better to use a fingerprint seg-ment to minimize the extraction time and the memory space.
- We can use Euclidean distance to re-place the points coordinates in the identifier, making the identifier small-er and easier to handle.
- The obtained identifier for each fin-gerprint is unique, and it can be accu-rately used to retrieve the fingerprint in a recognition system

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