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Analysis Methods Used to Extract Fingerprints Features

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ABSTRACT

The fingerprint is used in many vital applications important to humans, which requires searching for an effective way to extract the characteristics of the fingerprint. In this paper we will study some of the most popular methods used to extract fingerprints features. For each method the efficiency, accuracy, flexibility and sensitivity for image rotation will be experimentally tested, measured, analyzed in order to give good recommendations of how and when to use a certain method of features extraction. A detailed comparison analysis between MLBP, K_means, WPT, Minutiae methods will be done using several color images in various rotation modes to insure the stability of image features.

1. INTRODUCTION

Fingerprints are prominent bumps in the skin that are adjacent to depressions, and each person has a distinct shape, and it has been proven that the fingerprint cannot be identical and identical in two people in the world even the identical twins that originate from one egg, and these lines leave their impact on everybody that touches it and on the surfaces Particularly smooth. Therefore, fingerprint recognition refers to the mechanism for verifying the compatibility of the two fingerprints of a person, and the fingerprint is one of the types of biometrics used to verify and document identity [1].

People have small bumps on their fingers, which make it easier to catch things. Like every organ of the human body, these protrusions are formed by genetic and environmental factors, which give the genetic code of DNA the basics on which the developing gene must form [2]. But the way to configure it depends on random events. Like the position of the fetus in the womb at a given moment, the concentration and density of the placenta fluid surrounding the fetus, they decide how each bump will form. So, in addition to the countless factors that interfere with a person's genetic makeup, there are many environmental factors that influence finger formation. The development process is very messy, like the weather that forms clouds, so there can be no duplicate fingerprint twice [3].

Therefore, the fingerprint is a unique personal mark even in identical twins. Although a sneak peek at two fingerprints may turn out to be the same, a professional investigator or advanced program can spot the difference. This is the basic idea for fingerprint analysis in both protection and crime investigation [4].

Fingerprints can be represented by 2D or 3D matrix (gray or color image), and the matrix usually has a big size which make the process of identifying fingerprint very complicated in terms of time, for this reason, it is necessary to search for a way to represent the fingerprint with a group of limited values of small size, so that these values can be used as a classifier or identifier of the fingerprint.

Fingerprint features are a vector of small number of values, and each fingerprint features vector must satisfy the following requirements:

1) It must be unique for each fingerprint.
2) Easy to extract.
3) Must be numeric and easy to use.
4) Must not sensitive to the fingerprint rotation and it must be fixed.

Each fingerprint image can be represented by a histogram, and here we can benefit from an important feature of the image histogram, this feature is represented by the stability of the histogram and not affected by the result of rotating the image and to what degree as shown in Figures 1 and 2 [5].

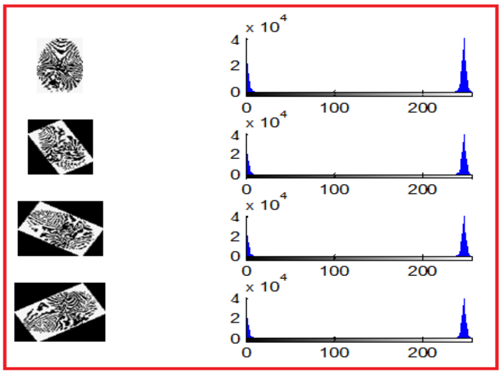


Figure 1. Fingerprint rotations

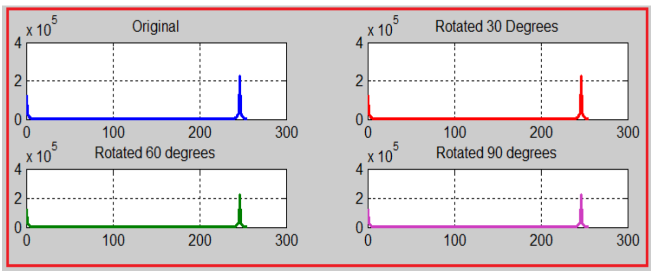


Figure 2. Fingerprint's histograms (histograms are stable)

2. FEATURES EXTRACTION METHODS

Multiple methods are used to extract the features of the fingerprint, and these methods vary in their efficiency, flexibility and degree of stability of features, especially after the rotation of the fingerprint. We will address in this item some of the commonly used methods: K_means clustering (K_means), Minutiae, modified local binary pattern (MLBP) and wavelet packet tree decomposition (WPT) methods.

2.1 K_means method

This method is based on grouping the image pixels into groups called clusters, this method is flexible by using the clusters centroids or the within clusters sums as a fingerprint features, the number of features in the features vector depends on the selected number of clusters. This method can use a fingerprint image or the image histogram as an input data set.

This method can be implemented applying the following steps:

Step1: Initialization: Select the number of clusters, the centroid for each cluster and the input data set.

Step2: While the centroids keep changing do the following.

Calculate the absolute value of distance between each point and each cluster centroid.

Depending on the distances calculated values add the point to the closest cluster, and then save the point coordinates.

Update each centroid by the using the average of the points which belong to the cluster.

Here is an example of clustering the following input data set into two clusters:

3	7	9	11	20	36	40	42

Tables 1, 2, 3, and 4 show the calculation processes.

From Table 4 we can see that the clusters centroids are: C1=17.1250 and C2=39.3333, the input data set was grouped into two clusters with points:

Cluster 1: 3, 7, 9, 11, 20

Cluster 2: 36, 40, 42

Table 1. Pass 1 C1=6, C2=12

Data item(point)	Distance 1	Distance 2	Nearest cluster	New centroids
3	3	9	**1**	
7	1	5	**1**	C1=6.3333
9	3	3	**1**	
11	5	1	**2**	
20	14	8	**2**	
36	30	24	**2**	C2=29.8000
40	34	28	**2**	
42	36	30	**2**	

Table 2. Pass 2 C1=6.3333, C2= C2=29.8000

Data item(point)	Distance 1	Distance 2	Nearest cluster	New centroids
3	3.3333	26.8000	1	
7	0.6667	22.8000	1	C1=7.5000
9	2.6667	20.8000	1	
11	4.6667	18.8000	1	
20	13.6667	9.8000	2	
36	29.6667	6.2000	2	C2=34.5000
40	33.6667	10.2000	2	
42	35.6667	12.2000	2	

Table 3. Pass 3 C1=7.5000, C2= C2=34.5000

Data item(point)	Distance 1	Distance 2	Nearest cluster	New centroids
3	4.5000	31.5000	**1**	
7	0.5000	27.5000	**1**	C1=17.1250
9	1.5000	25.5000	**1**	
11	3.5000	23.5000	**1**	
20	12.5000	14.5000	**1**	
36	28.5000	1.5000	**2**	C2=39.3333
40	32.5000	5.5000	**2**	
42	34.5000	7.5000	**2**	

Table 4. Pass 4 C1=17.1250, C2= C2=39.3333

Data item(point)	Distance 1	Distance 2	Nearest cluster	New centroids
3	14.1250	36.3333	**1**	**C1=17.1250**
7	10.1250	32.3333	**1**	No changes
9	8.1250	30.3333	**1**	so stop
11	6.1250	28.3333	**1**	
20	2.8750	19.3333	**1**	**C2=39.3333**
36	18.8750	3.3333	**2**	No changes
40	22.8750	0.6667	**2**	so stop
42	24.8750	2.6667	**2**	

2.2 Minutiae method

Fingerprint image contains several unique objects each of them is called minutiae as shown in Figures 3 and 4, each of them has its own shape, coordinates and orientation [5].

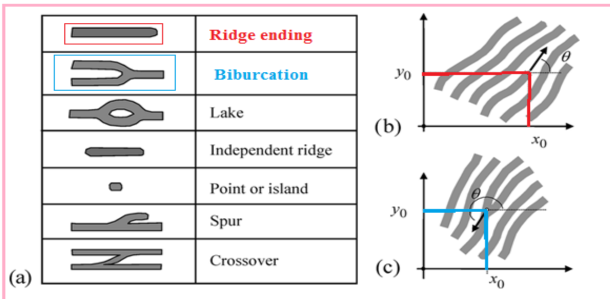


Figure 3. a) Minutiae types b) Coordinates c) Orientation

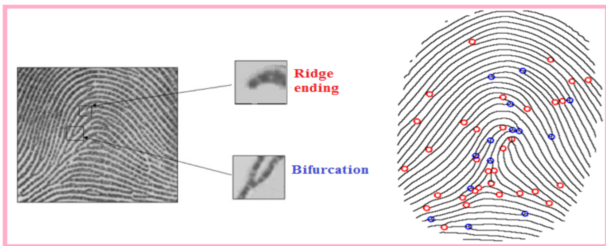


Figure 4. Fingerprint structure

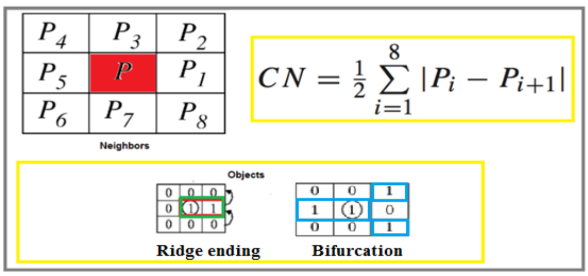


Figure 5. CN calculation

Here we will focus on detecting ridge ending and bifurcation minutiae, and here we can use the counts of each of them and the distances as a fingerprint feature.

Each minutia in the fingerprint image can be easily detected depending on the 8 neighbors values and using the calculated classifier crossing number (CN) as shown in Figure 5 [6].

The Euclidean distance for each object points can be calculated using formula (1) (where n is the number of points in each object).

$$d(\boldsymbol{p},\boldsymbol{q}) = d(\boldsymbol{q}.\boldsymbol{p}) = \sqrt{(q_1-p_1)^2+(q_2-p_2)^2+\cdots+(q_n-p_n)^2} = \sqrt{\sum (q_i-p_i)^2} \quad (1)$$

This method can be implemented applying the following steps:

Step1: Get the digital image.

Step2: If the digital image is color, then convert it to gray image.

Step3: Convert the gray image to binary.

Step4: Apply morphological thinning to get the image edges.

Step5: For each pixel in the image do the following:

Calculate CN.

Determine the object depending on CN value.

Add 1 to the object count.

Get the pixel coordinates.

Add the coordinates to the points coordinate matrix.

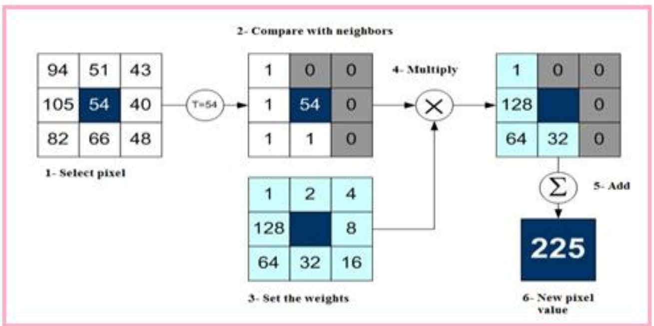
Step6: For each detected object calculate Euclidean distance.

Step7: Use the object counts and distances as a fingerprint features [7].

2.3 Modified local binary pattern method

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.

LBP image can be obtained applying the steps shown in Figure 6.



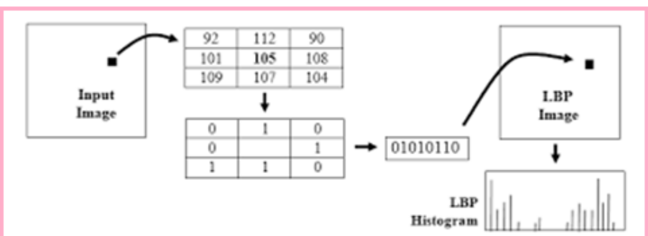


Figure 6. Example of calculating LBP pixel

The introduced MLBP method is based on LBP operator calculation, this method is flexible and we can select the number of features for each fingerprint freely, the following Table 5 shows how to use this method to extract 4-elements features vector for each finger print [8]:

Table 5. MLBP calculation

Pixels	…..	100	**120**	**150**	**80**	**170**	**90**	130	…..
150<= 170, so b0=1 120 not <=170 so b1=0 Binary number=01, decimal =1 So add 1 to count of features vector with index=1 These operations to be repeated for each pixel, at the end we got a vector of for values									

2.4 WPT decomposition method

Wavelet packet tree decomposition can be used to extract features for any fingerprint by reshaping the image matrix into one row matrix, then calculating the approximation and details using formulas 2 and 3 [8]. Here we can control the features vector size by selecting the decomposition level, and taking only the obtained approximation as shown in Figure 7.

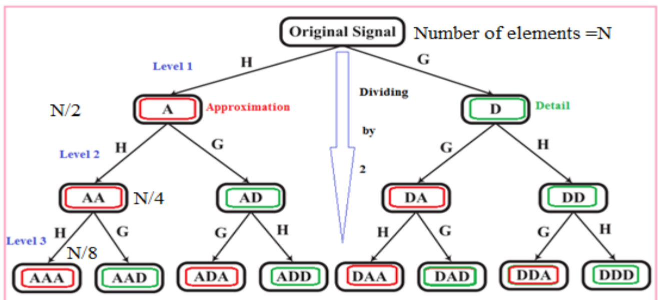


Figure 7. WPT decomposition

$$A_{j+1,i} = \frac{even_{j,i} + odd_{j,i}}{2} \quad (2)$$

$$D_{j+1,i} = \frac{even_{j,i} + odd_{j,i}}{2} \quad (3)$$

Table 6 shows an example of how to calculate approximations and details:

Table 6. Approximations and details calculation example

	3	7	9	11	20	36	40	42
Level 1	Approximation				Detail			
	5	**10**	**28**	**41**	**-2**	**-1**	**-9**	**-1**
Level 2	Approximation		Detail		Approximation		Detail	
	7.5	**34.5**	**-2.5**	**-6.5**	**-1.5**	**-5**	**-0.5**	**-4**
Level 3	Approximation	Detail	Approximation	Detail	Approximation	Detail	Approximation	Detail
	21	-13.5	-4.5	2	-3.25	1.75	-2.25	1.75

3. IMPLEMENTATION AND EXPERIMENTAL RESULTS

3.1 K_means clustering implementation

The main disadvantage of this method is that it requires high extraction time especially for images with big sizes, this will reduce the efficiency of this method, and Table 7 shows the results of K-means clustering using images with big sizes [9].

To overcome the previous mentioned disadvantage we can use the fingerprint image histogram as an input data set for clustering, Table 8 shows the obtained results for the selected 10 fingerprints images.

From Table 8 we can see the following facts:

-K_means is efficient by providing an average extraction time of 0.07 seconds.

The obtained features for each fingerprint image are unique.

-K_means method is flexible in selecting the features vector size, which equal the number of cluster.

-K_means methods can give us an alternative feature by selecting the within clusters sums as a features.

-K_means method is not sensitive to the fingerprint rotation; they keep the same without any changes even if the image was rotated as shown in Table 9.

(Rotation degrees were selected as an example; here we can select any rotation degree).

3.2 MLBP implementation

MLBP method of features extraction is efficient for images with various sizes; Table 10 shows the obtained experimental results using images with various sizes.

The same images were rotated 45 degrees, Table 11 shows the obtained results.

Table 7. K_means extraction time for big images (4 clusters)

Image number	Size(byte)	Centroids(features)				Extraction time(seconds)
F1	**5140800**	**26.2997**	**77.3687**	**130.4123**	**197.0929**	**31.735000**
F2	**6119256**	**63.9469**	**110.3634**	**148.1826**	**228.5058**	**35.637000**
F3	**150849**	**24.7795**	**88.6582**	**162.6748**	**230.7880**	**2.310000**
Extraction time rapidly increases when the image size increases.						

Table 8. Fingerprint images features (K_means clustering)

Fingerprint #	Size (byte)	Features(centroids)				Extraction time (seconds)
		Cluster 1	Cluster 2	Cluster 3	Cluster 4	
1	231000	350	7150	74180	261000	0.072000
2	3935100	900	11900	55600	1021700	0.083000
3	98256	170	3240	24610	102680	0.068000
4	151050	72	477	16624	56269	0.069000
5	151122	81	621	19845	57190	0.108000
6	532500	270	5080	70520	193540	0.091000
7	2104050	570	23670	223320	872240	0.074000
8	151200	97	419	14280	56355	0.071000
9	151050	69	577	7057	56337	0.068000
10	150897	79	702	20531	54726	0.081000
Average	**765620**					**0.0785**

Table 9. Features for fingerprint 1 and various rotated versions

Fingerprint	Size (byte)	Features(centroids)				Extraction time (seconds)
		Cluster 1	Cluster 2	Cluster 3	Cluster 4	
1	231000	350	7150	74180	261000	0.072000
Rotated 25 degrees	231000	350	7150	74180	261000	0.072000
3 Rotated 60 degrees	231000	350	7150	74180	261000	0.072000
Rotated 135 degrees	231000	350	7150	74180	261000	0.072000

Table 10. MLBP results (images with various sizes)

F1	**5140800**	**1748515**	**690226**	**667124**	**2034931**	**0.1940**
F2	**6119256**	**1566343**	**1027114**	**969247**	**2556548**	**0.2380**
F3	**150849**	**57977**	**23237**	**20181**	**49450**	**0.0060**
Extraction time is significantly small for various image sizes.						

Table 11. MLBP features for rotated images

Image number	Size(byte)	Centroids(features)				Extraction time(seconds)
F1	**5140800**	**1748515**	**690226**	**667124**	**2034931**	**0.1940**
F1 rotated 45 degrees	**5140800**	1792257	671778	635231	7605693	0.1940
F2	**6119256**	**1566343**	**1027114**	**969247**	**2556548**	**0.2380**
F2 rotated 45 degrees	**6119256**	1467454	1097850	1061771	9264908	0.2380
F3	**150849**	**57977**	**23237**	**20181**	**49450**	**0.0060**
F3 rotated 45 degrees	**150849**	55753	25958	20693	254667	0.0060
Extraction time is significantly small for various image sizes.						

Table 12. Fingerprint MLBP features

Fingerprint #	Size (byte)	Features				Extraction time (seconds)
1	231000	65	50	59	78	0.0350
2	3935100	78	36	41	97	0.0330
3	98256	78	43	49	82	0.0230
4	151050	66	47	53	86	0.0240
5	151122	70	49	50	83	0.0230
6	532500	68	48	41	95	0.0240
7	2104050	84	39	41	88	0.0300
8	151200	60	50	53	89	0.0240
9	151050	66	53	55	78	0.0220
10	150897	61	40	37	114	0.0240
Average	**765620**					**0.0262**

From Table 11 we can see that MLBP method is very sensitive to image rotations, and to overcome this disadvantage we can use the image histogram to find the fingerprints features, Table 12 shows the results for the selected 10 fingerprint images.

From Table 10 we can raise the following facts related to MLBP method:

-The method is efficient by providing a small average time of features extraction.

-The obtained features for each fingerprint image are unique.

-Using histogram will reduce the extraction time and will keep the features without any changes even if the image was rotated.

3.3 WPT decomposition implementation

Fingerprint images usually have different sizes, so it is difficult to determine the levels of decomposition to get the needed size of features vector, to overcome this disadvantage we can use the fingerprint image histogram, the selected fingerprints were processed using this method and Table 13 shows the experimental results:

Table 13. Fingerprint WPT features

Fingerprint #	Size (byte)	Features				Extraction time (seconds)
1	231000	8410	1889	1895	16682	0.0990
2	3935100	3795	345	279	11978	0.1290
3	98256	34114	8060	7861	72785	0.1000
4	151050	15543	4580	4735	38080	0.0990
5	151122	1181.8	431	527.8	4156.3	0.1130
6	532500	6125	1102	1196	13765	0.1710
7	2104050	29086	2119	2192	54272	0.1000
8	151200	13630	6221	7494	35655	0.0980
9	151050	1544.6	386.1	449.5	3913.5	0.1010
10	150897	264.9	1405.9	482.4	4175.0	0.1060
Average	**765620**					**0.1116**

Table 14. Minutiae features

Fingerprint #	Size (byte)	Features				Extraction time (seconds)
		Ridge ending	Bifurcation	DR	DB	
1	231000	655	2444	500.6755	451.5496	0.4500
2	3935100	69	2379	461.7359	992.3719	2.2630
3	98256	39	1149	240.4683	301.0814	0.1640
4	151050	6	375	188.7326	101.8332	0.0980
5	151122	15	229	31.3847	193.7524	0.0900
6	532500	37	512	367.7839	298.4024	0.3000
7	2104050	48	2853	966.6276	844.4104	1.2210
8	151200	2	53	106.4519	238.8326	0.1040
9	151050	7	368	223.8928	101.8332	0.0900
10	150897	14	138	94.8103	236.1779	0.1120
Average	**765620**					**0.4892**

From Table 13 we can raise the following facts related to WPT decomposition method:

-The method is efficient by providing a small average time of features extraction 9 with average time =0.11 seconds).

-The obtained features for each fingerprint image are unique.

-Using histogram will reduce the extraction time and will keep the features without any changes even if the image was rotated.

-The method is flexible of determining the features vector size by selecting the necessary level of approximation.

3.4 Minutiae method of features extraction

Here we select the ending ridges and bifurcations and used the counts of ridge points, the counts of bifurcation, the Euclidean distances for both ridge ending and bifurcation objects, Table 14 shows the obtained experimental results, and from this table we can raise the following facts related to minutiae:

-The method is efficient by providing a small average time of features extraction 9 with average time =0.48 seconds).

-The obtained features for each fingerprint image are unique.

-Using histogram will destroy the minutiae objects.

-Rotating the fingerprint will produce different features, so we have to keep more than one version for each fingerprint associated with the same person.

-The method is flexible of determining the features vector size by selecting the necessary number of objects depending on CN value.

Table 15 shows the ridge ending coordinates for fingerprint 4, while Figures 8 and 9 show the plot of these points.

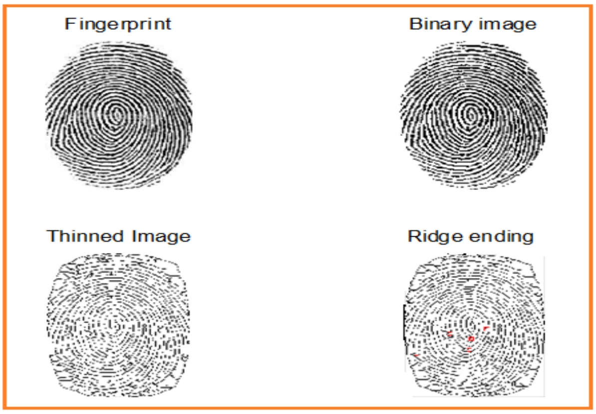


Figure 8. Ridge ending for fingerprint 4

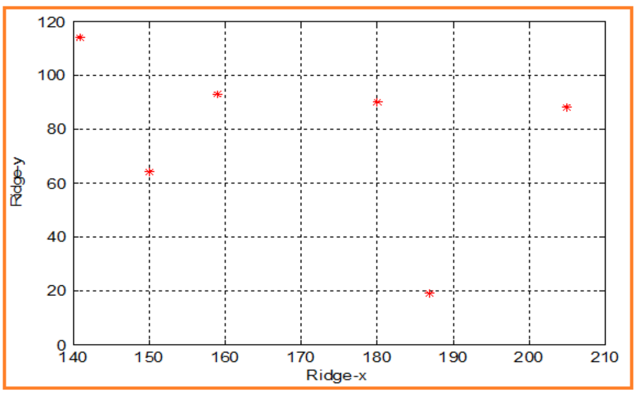


Figure 9. Plot of ridge ending for fingerprint 4

Table 15. Ridge ending for image 4

Ending ridge points coordinates	
Ridge_x	Ridge_y
187	19
150	64
205	88
180	90
159	93
141	114

For efficiency comparisons we took the extraction time for each method as shown in Figure 10 (Minutiae has the worst efficiency, while MLBP has the best):

K_means	MLBP	WPT	Minutiae
0.072	0.035	0.099	0.45
0.083	0.033	0.129	2.263
0.068	0.023	0.1	0.164
0.069	0.024	0.099	0.098
0.108	0.023	0.113	0.09
0.091	0.024	0.171	0.3
0.074	0.03	0.1	1.221
0.071	0.024	0.098	0.104
0.068	0.022	0.101	0.09
0.081	0.024	0.106	0.112

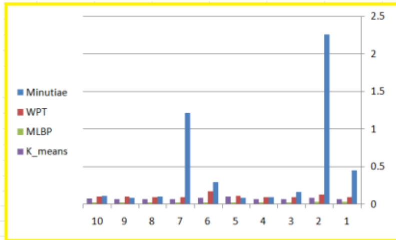


Figure 10. Time comparisons

All the studied methods are not sensitive to image rotation except minutiae method, because taking the histogram will destroy the objects structures within the fingerprint, and this show in Table 16:

Table 16. Various methods features

Fingerprint	K_means	MLBP	WPT	Minutiae
1	350	65	8410	655
	7150	50	1889	2444
	74180	59	1895	500.6755
	261000	78	16682	451.5496
1 rotated 35 degree	350	65	8410	594
	7150	50	1889	2266
	74180	59	1895	220.6354
	261000	78	16682	239.0063
	No changes	No changes	No changes	**Changed**

The way that section titles and other headings are displayed in these instructions, is meant to be followed in your paper.

4. CONCLUSIONS

Various methods for fingerprint features extraction were introduced, implemented and analyzed. Experimental results showed that using histogram will improve the efficiency of K-means, MLBP, and WPT method. K_means method features are stable even if we rotate the fingerprint image. Using image histogram in MLBP and WPT methods will fix the features and will keep them without changes even if we rotate the image. Using Histogram in minutiae method is not recommended because it destroys the fingerprint structure.

It is mandatory to have conclusions in your paper. This section should include the main conclusions of the research and a comprehensible explanation of their significance and relevance. The limitations of the work and future research directions may also be mentioned. Please do not make another abstract.

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