RESEARCH ARTICLE

Detecting and Counting Minutiae in Human Fingerprint

Ziad Abdel AlQadi¹*, Yousf Eltous¹, Mohammad Abuzalata¹, Ghazi M. Qaryouti¹

¹Faculty of engineering technology, Jordan

*Corresponding author: Ziad A. AlQadi: natalia_maw@yahoo.com

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. Fingerprint 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. Fingerprint 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
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]:

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]:

\[ P_{in}(r_k) = \frac{n_k}{n}, \quad 0 \leq r_k \leq 1, \quad 0 \leq k \leq L - 1 \]  

(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:

\[ S_k = T(r_k) = \sum_{j=0}^{k} P_{in}(r_j), \quad 0 \leq k \leq L - 1 \]  

(2)

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

| Gray level(r_k) | No. of Pixels(n_k) | PDF\( \frac{n_k}{N} \) | 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):

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         | 8                         |
| 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 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    | 0               | 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:
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

| Fingerprint | Size   | Used size | Isolated points | Ridge ending | Continuation 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)

Table 9: Experiment 2 c) results

| Fingerprint | Size   | Used size | Isolated points | Ridge ending | Continuation 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.

| 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
References:

1. Jude Hemanth & Valentina Emilia Balse, ed. (2018). Biologically Rationalized Computing Techniques For Image Processing Applications. Springer, p. 116. ISBN 9783319613161.

2. Ronald F. Becker & Arc W. Dutelle (2018). Criminal Investigation. Jones & Bartlett Learning, p. 133. ISBN 9781284049285.

3. Fingerprinting of UK school kid's cause's outcry Archived August 10, 2017, at the Way back Machine, The Register, and July 22, 2002 (in English).

4. Fingerprint Source Book: manual of development techniques, published 26 March 2013 Archived February 11, 2017, at the Way back Machine retrieved on February 9, 2017; see also Max M. Houck (Ed.): Forensic Fingerprints, London 2016, p. 21, 50 er.

5. Ziad A.A. Alqadi, Musbah Aqel, Ibrahim M. M. El Emamy, Fingerprint Matching Algorithm Based on Ridge Path Map, European Journal of Scientific Research ISSN 1450-216X Vol.15 No.3 (2006), pp. 344-351.

6. Ziad A. Alqadi, Majed O. Al-Dwairi, Amjad A. Abu Jazar and Rushdi Abu Zneit, Optimized True-RGB color Image Processing, World Applied Sciences Journal 8 (10): 1175-1182, ISSN 1818-4952, 2010.

7. A. A. Moustafa, Z. A. Alqadi, Color Image Reconstruction Using A New R’G’I Model, Journal of Computer Science, Vol.5, No. 4, pp. 250-254, 2009.

8. Jamil Al Azzeh, Hussein Alhatamleh, Ziad A. Alqadi, Mohammad Khalil Abuzalata, Creating a Color Map to be used to Convert a Gray Image to Color Image; International Journal of Computer Applications, November 2016, Volume 153, Issue 2.

9. Alqaisi Aws and ATTarawneh Mokhled and Alqadi Ziad A. and Sharadqah Ahmad A. Analysis of Color Image Features Extraction using Texture Methods, TELKOMNIKA, volume 17, number 3, pages 1175–1182, year 2019.

10. Al-Azzez J., Zahran B., Alqadi Ziad, Ayyoub B. and Abu-Zaheer, M., A novel zero-error method to create a secret tag for an image, Journal of Theoretical and Applied Information Technology, volume 96, number 13, pages 4081-4091, year 2018.

11. Moustafa, A.A., Alqadi, Ziad A., A practical approach of selecting the edge detector parameters to achieve a good edge map of the gray image, Journal of Computer Science, volume 5, number 5, pages 355-362, year 2009.

12. Al-Dwairi Majed O and Alqadi Ziad A and Abu Zneit, Rushdi Abu, Optimized true-color image processing, World Applied Sciences Journal, volume 9, number 10, pages 1175-1182, year 2010.

13. Jamil Al Azzeh, Ziad A. Alqadi, Hussein Alhatamleh, Mohammad Khalil Abuzalata, Creating a Color Map to be used to Convert a Gray Image to Color Image, International Journal of Computer Applications (0975 – 8887), volume 153, number 2, pages 31–34, year 2016.

14. Zahran Bilal and Al-Azzez, Jamil and Alqadi Ziad and Al Zoghoul, Mohd-Ashraf, A Modified Lbp Method To Extract Features From Color Images, Journal of Theoretical and Applied Information Technology, volume 96, number 10, pages 3014–3024, year 2018.

15. Zudool, Mohammed Ashraf Al and Khawatreh, Saleh and Alqadi Ziad A., Efficient Methods used to Extract Color Image Features, IJCSMC, volume 6, number 12, pages 7–14, year 2017.

16. Bilal Zahran, Ziad Al-Azzeh, Ziad Alqadi, Mohd-Ashraf Alzoghoul, Saleh Khawatreh, A modified Ibp method to extract features from color images, Journal of Theoretical and Applied Information Technology 31st May 2018. Vol.96. No 10.

17. Saleh Khawatreh, Belal Ayyoub, Ashraf Abu-Ein, Ziad Alqadi, A Novel Methodology to Extract Voice Signal Features, International Journal of Computer Applications (0975 – 8887) Volume 179 – No.9, January 2018.

18. Majed O. Al-Dwairi, Amjad Y. Hendi, Mohamed S. Soliman, Ziad A.A. Alqadi, A new method for voice signal features creation, International Journal of Electrical and Computer Engineering (IJECCE) Vol. 9, No. 5, October 2019, pp. 4092-4098 ISSN: 2088-8708, DOI: 10.11591/ijjce.v9i5.pp4092-4098.

19. Jihad Nader, Ziad A. A. Alqadi, Bilal Zahran, Analysis of Color Image Filtering Methods, International Journal of Computer Applications (0975 – 8887) Volume 174 – No.8, September 2017.

20. Ay, Nihat; Amari, Shun-ichi (2015). "A Novel Approach to Canonical Divergences within Information Geometry" (PDF). Entropy. 17 (12): 8111–8129. Bibcode: 2015Entrp...178111A. doi:10.3390/e17128766.

21. Ahmad Sharadqah Naseem Asad, Ismail Shayeob, Qazem Jaber, Belal Ayyoub, Ziad Alqadi, Creating a Stable and Fixed Features Army for Digital Color Image, IJCSMC, v. 8, issue 8, pp. 50-56, 2019.

22. Majed O. Al-Dwairi, Amjad Y. Hendi, Mohamed S. Soliman, Ziad A.A. Alqadi, A new method for voice signal features creation, International Journal of Electrical and Computer Engineering (IJECCE), v. 9, issue 5, pp. 4092-4098, 2019.
23. Qazem Jaber Ziad Alqadi, Jamil azza, Statistical analysis of methods used to enhance color image histogram, XX International scientific and technical conference, 2017.
24. Ziad Alqadi, A modified lbp method to extract features from COLOR IMAGES, Journal of Theoretical and Applied Information Technology, v. 96, issue 10, pp. 3014-3024, 2018.
25. Saleh Khawatreh, Belal Ayyoub, Ashraf Abu-Ein, Ziad Alqadi, A Novel Methodology to Extract Voice Signal Features, International Journal of Computer Applications, v. 975, pp.8889, 2018.
26. Bilal Zahran Belal Ayyoub, Jihad Nader, Ziad Al-Qadi, Suggested Method to Create Color Image Features Victor, Journal of Engineering and Applied Sciences, v. 14, issue 1, pp. 2203-2207, 2019.