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User identification system for inked fingerprint pattern based on central moments

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ABSTRACT

The use of the fingerprint recognition has been and remains very important in many security applications and licensing systems. Fingerprint recognition is required in many areas such as licensing access to networks, corporate computers and organizations. In this paper, the system of fingerprint recognition that can be used in several cases of fingerprint such as being rounded at an angle by a randomly inked fingerprint on paper. So, fingerprint image is tooked at a different angle in order to identify the owner of the ink fingerprint. This method involves two working levels. The first one, the fingerprint pattern's shape features are calculated based on the central moments of each image being listed on a regular basis with three states rotation. Each image is rotated at a specified angle. In the second level, the fingerprint holder entered is identified using the previously extracted shape features and compared to the three local databases content of three rotation states. When applied the method for several persons by taken their inked fingerprint on the paper, the accuracy of the system in identifying the owner of the fingerprint after rotation states were close to 83.71.

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1. INTRODUCTION

Fingerprint recognition is one of the oldest and most important research areas in the field of pattern recognition. One of the basic problems in the design of an imagery pattern identification system is the selection of a set of the suitable numerical characteristic that is extracted from the object for the target of identification and classification [1]–[10]. Simple characteristic of the image which is found through of image moments includes any area the higher-order, the moments give more detailed shape features of the objects such as symmetry [11]–[17]. Geometrical moments current a low computational cost but are highly susceptible to the noise [18], [19]. Moreover, rebuilding is extremely difficult although not invariant under rotation. Chaorong *et al.* [20] and Xiao *et al.* [21] work on the transformation of normalization for central moments to produce the performing moments invariant. Arnia *et al.* [22] have used the moments for character recognition and the mathematical concept of moments. Related invariants have been analyzed extensively to characterize the patterns in images in a variety of applications, such as fingerprint identification and recognition. The moments have been used in many applications from mechanism and statics to image conception. Analysis images with moments instead of other more generally utilized image features means that general characteristic of the image is utilized indeed than the local characteristic [1], [11]–[17], [23], [24].

Fingerprints have been used in the identification/recognition of persons in many recent years because of the known truth that each finger has a unique pattern for each human [25]–[34]. Fingerprint identification/recognition has very good scales of the entire desired characteristic like authentication, and every human being possesses fingerprints with the exception of any finger patterns-related failure [2], [13], [33], [35]. Fingerprints are very special, and the details of the fingerprint are imperishable, even if they may tentatively change by little cuts and bruise on the skin or weather effects [9], [12], [35]–[41]. It is typically used in security systems and is compared to other biometrics such as face recognition systems [42]–[62].

Many works dealing with fingerprint verification task is present in recent years [2], [3], [6]–[8], [10]–[12], [15], [18], [20], [28], [29], [34], [37]–[39], [41], [44]-[47], [57], [58], [63]–[89]. Kommini *et al.* [63] and Sharma *et al.* [72] presented a method of fingerprint recognition based on fractal features extracted of the separated image. These features are extracted from the gray level of fingerprint images without any preprocessing operations This method may be an efficient algorithm for a small fingerprint recognition system. Abdalkafor [64] built a new database for fingerprint recognition system of ink on paper fingerprint for Alanbar University staff. In his research was training about 170 fingerprints, without any notations of system accuracy. Some traditional processing operations such as RGB convert and segmentation have been applied [9], [50], [71], [72], [90]–[99]. Cao and Jain [65] presented a latent fingerprint identification method based on convolutional neural networks for ridge assessment and texture extraction to represent the latent. Their identification method performance is improved from 64.7% to 73.3% on National Institute of Standards and Technology and 76.6% on West Virginia University latent databases. Other researchers [38], [70], [74] also employed convolutional neural network for fingerprint identification. Chaorong *at el.* [20] presented a method for rotation and scale-invariant of the reference point locates in the corner of the input image. The method is based on fast Zernike moments algorithm. The results of their experiment show the proposed method has high verification accuracy in computational time (0.533s) than most of the texture extraction methods. And Noor *et al.* [66] presented a new method for identification of fingerprints using FV2002 database. Some of preprocessing operations are used on fingerprints image, then features are extracted to build their database. Fingerprint recognition method is presented by image classification by DT, LDA, and SVM [88], [89], [100]. By excremental results, SVM classifiers safely give the highest realization rate of 98.90% comparing with all classifies used in this work. In the proposed system, for identification of inked fingerprint based on central moments to extract shape features of a inked image fingerprint pattern entered, then take a number of cases of fingerprint one-person job rotation of the fingerprint by: (0-45),(45-90), and (90-180) angles and then extract the image properties (shape features) based on the values of moments, these features are used in the recognition level for identification system.

2. FEATURES EXTRACTION

In the feature extraction level, the method is depending on the binary image by 0/1, and shape attribute extracted by central moments. Image threshold and preprocessing techniques like enhancement, thinning for binary image, is required for this application in order to remove noise effect and to simplify the test image processing. Preprocessing steps include several traditional image processing methods which are applied together to obtain a better input data for features extraction step [11], [34], [40], [58], [70], [83], [101]–[103].

2.1. Fingerprint Structure

A comprehensive study has been done on human's fingerprints. Two of the principally remarkable inferences are: 1) a human's fingerprint surely unchanged its patterns about one year after birth, and 2) the fingerprints of humans are unique. Even twins' fingerprints are not the same. In practical, two persons with the same fingerprint have never been found [35], [36], [104]. A fingerprint pattern involves ridges and valleys. More detail of a fingerprint pattern is shown in Figure 1. The ridges are the dark area of the fingerprint and the valleys are the white area that exists between the ridges, that ridges represent the shape of the fingerprint [105], [106].

Figure 1. Fingerprint Ridges and Valleys pattern

2.2. Preprocessing Operations

In this work before the feature extraction is conducted, the fingerprint image is processed through four stages preprocessing operations needed to facilitate the sequent analysis of the image for fingerprint texture features extraction.

1. Gray scale Image: the color inked of fingerprint image was converting to gray image.
2. Binary Image: convert gray fingerprint image to binary image.
3. Enhancement: edge smoothing is used to plug the gap in ridge detail. The gaps are a product of the fineness of the input fingerprint image, parallel ridges linked causes noise and other effects to the fingerprint such as cuts, crease, and damage. The enhancement of fingerprint image is expected to give better contrast between ridges and valleys and decrease noises. In the fingerprint images, the median filter is applied to decrease the noise from the gray scale image.
4. The ridges are thinned to a width of one-pixel. In this step, two consecutive fast parallel thinning algorithms are applied in order to reduce the width of the ridges to a single pixel in the binary image.

2.3. Moments Features

In many applications such as shape recognition, it is useful to generate shape features which are independent of parameters which cannot be controlled in an image. Such features are called invariant features. There are several types of invariances. There are a many different features available that are used in image classification and retrieval, the grade of similarity between query/test new fingerprint images and the images stored in the database system is computed by color [19], [107]–[109] spread, texture, shape identity [110]. Studying digital images using shape features have attracted more interest, and moreover the representation/description of the shape features is a complex job [1], [35], [101].

Moment invariants have been frequently used as attributes in the digital image analysis, remote sensing, shape identifier, and classification. Moments provide features of an object that uniquely represent its shapes such as fingerprint or hand palm. Invariant shape identifier is performed by classification in the multi-space moment invariant feature [19], [107]. In image processing, computer vision and related fields, an image moment is a certain particular weighted average (moment) of the image pixels' intensities, or a function of such moments, usually chosen to have some attractive property or interpretation [108]–[112].

Central moments [113]–[115] are defined as:

$$\mu_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q \, f(x,y) dx\, dy \tag{1}$$

Where: $\bar{x} = \frac{M_{10}}{M_{00}}$ and $\bar{y} = \frac{M_{01}}{M_{00}}$ are the components of the centroid.
When $f(x,y)$ is a digital image, (1) becomes:

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q \, f(x,y) \tag{2}$$

2.4. Rotation invariants [1], [22]

Invariants with respect to translation, scale, and rotation is constructed, these are well-known as Hu moment invariants, where Moments (μ_{pq}) is the projection of image ϱ (x,y) to basis ($x^{p,}$ y^{q}), and ϱ (x,y) is the piecewise continuous function with non-zero values in a portion of the plane.

$$\partial 1 = \eta 20+\eta 02 \tag{3}$$

$$\partial 2 = (\eta 20+\eta 02)2+4\ \eta\ 2\ 1 \tag{4}$$

$$\partial 3 = (\eta 30+3\eta 12)2+(3\eta 21+\eta 03)2 \tag{5}$$

$$\partial 4 = (\eta 30+\eta 12)2+(\ \eta 12+\eta 03)2 \tag{6}$$

$$\partial 5 = (\eta 30+3\eta 12)(\eta 30+\eta 12)[(\eta 30+\eta 12)2-3(\eta 21+\eta 03)2]+(3\eta 21-\eta 03)(\eta 21+\eta 03) \quad (7)$$

$$\partial 6 = (\eta 20+\eta 02)[(\eta 30+\eta 12)2-3(\eta 21+\eta 03)2]+4\,\eta 11\,(\eta 30+\eta 12)(\eta 21+\eta 03) \quad (8)$$

$$\partial 7 = (3\eta 21-3\eta 03)(\eta 30+\eta 12)[(\eta 30+\eta 12)2-3(\eta 21+\eta 03)2]+ (3\eta 12-\eta 03)(\eta 21+\eta 03)[3(\eta 30+\eta 12)2-(\eta 21+\eta 03)2] \quad (9)$$

3. METHOD

The fingerprint images are acquired either by an offline or online process. The fingerprint images acquired by the offline process are known as the inked fingerprints, while the images acquired by the on-line process are known as live scan fingerprints. A live scan fingerprint is obtained directly from the finger without the intermediate use of paper. Typically, live scan sensors capture a series of bad fingerprints when a finger is pressed on the sensor surface [25]. In this case, there is rarely a problem in the image taken from the scan fingerprint device. The complexity in identifying of authorized user and identify his fingerprint by processing his inked fingerprint on the paper, especially since the fingerprint on paper is not regular but randomly, and at random angle at most cases that which work on this proposal system.

In this research, inked fingerprint off-line is used, therefore, have not used any live-scan sensors device in fingerprint acquisition. Ink is applied to the finger and then pressed onto a paper without rolling. The fingerprint on paper is then scanned as input digital image. Figure 2 shows the details of this methodology of the fingerprint identification system.

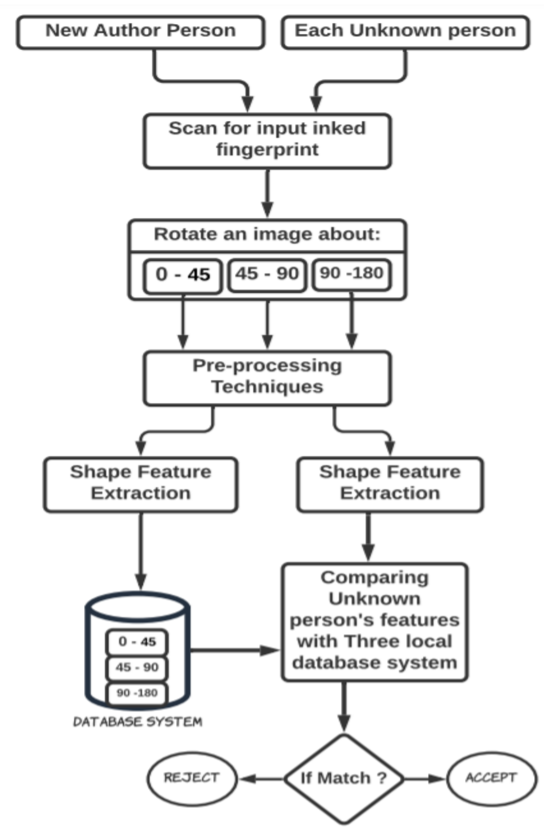

Figure 2. Identification system methodology

3.1. Fingerprint Shape Features

The inked fingerprint on the paper is used that set by the user. So, it is possible that the fingerprint irregular in terms of developing the finger on paper. It has placed randomly and trends variable time and again unlike a fingerprint taken from the devices sensitive to the fingerprint, which finger is placed in a specific place is not possible change of direction, before they enter to extracted its features based on central moment. Algorithm (1) is shown the databases system for features extraction from input fingerprint images.

Algorithm (1): Fingerprint features extraction

```
Input: scanned ink-on-paper Fingerprint image.
Output: three types of seven Moment features saved in a Database system for each Person's
fingerprint.
1. Input ink color for fingerprint image.
2. Image Rotation for only author user in one time about three angles state. That by using
   equations rotation [108]:
```

$$X_2 = (\cos\text{Ø} * (x_{1-}x_0)) - (\sin\text{Ø} * (x_{1-}x_0)) * (y_1 - y_0) - x_0 \quad (10)$$

$$Y_2 = (\sin\text{Ø} * (x_{1-}x_0)) - (\cos\text{Ø} * (x_{1-}x_0)) * (y_1 - y_0) - y_0 \quad (11)$$

```
   Where, (x0, y0) are the coordinates of the center of rotation for input image, and Ø is
   the angle of rotation with clockwise rotations having positive angles.
3. Preprocessing of image that result from Step 2. By:
   a. Convert Image in to Gray Scale Image.
   b. Convert Gray Image to Binary Image.
   c. Binary image Threshold.
   d. Thinning its boundary and limitation for ridges.
4. Based on Equations (3 to 9), obtained a set of seven features for fingerprint image
   input for each angles state.
5. Saved all moment features for all fingerprint images in Database system to use it in
   identification system for this proposed method by the following:
   If PF rotate about (0-45) degree then saved it in DB0
   If PF rotate about (45-90) degree then saved it in DB1
   If PF rotate about (90-180) degree then saved it in DB2
   Where, PF is Person's Fingerprint image, DB0, DB1, and DB2 are Local database.
```

The database system includes three local databases was divided according to the degree of rotation to the image of a fingerprint, and include the following:

1. Rotate the image specific angle between 0-45 degrees, store in DB0.
2. Rotate the image angle is restricted between 45 to 90 degrees, store in DB1.
3. Rotate the image for a certain angle between 90 to 180 degrees, store in DB2.

In all three states showing above, the applier of the system have a freedom to choose the degree of rotation in the range specified for each case, this matter as mentioned earlier will help in the development of several possibilities for the image fingerprint that will enter through a system of discrimination, which comes from the introduction of image a fingerprint through the paper content that fingerprint may not be subject by the person concerned to accept his mark in moderate any direction angle.

3.2. Fingerprint Identification

When applied of fingerprint features extraction steps from Algorithm (1) on the inked fingerprint image on the paper, maximum one object is defined, for this object (ridges connected) define the seven moments features. In the fingerprint identification system was show in Figure 2, each new unknown inked fingerprint image will be entered to the system for identification it. Firstly, an Algorithm (1) will be applied to extract of shape features without any rotate to get their 7 features moment to compare it with different fingerprint features stored in the local databases of database system (DB0, DB1, and DB2) to accept a new user or reject it. Identification fingerprint system is explained in Algorithm (2).

Algorithm (2): Fingerprint recognition and authentication system

```
Input: Unknown inked fingerprint image.
Output: Accept or Reject a new inked fingerprint image.
Applied Steps 3 and 4 in Algorithm (1) to get 7 Features for new Fingerprint input.
For each DB0, DB1, and DB2 do:
Compare the 7 Features from step 1 with each of 7 Features from each local database in the
database system by:
```

$$\text{F} = \sum_{i=1}^{7} \frac{F_{i\,P}}{F_{i\,DB}} * 14.28 \quad (12)$$

```
Where: F is the summation of ((F_(i P)/Fi DB)*14.28), it will between (14.28*7%) and
(100%), 14.28 is the average of (100/7) for 7 features.
(F_(i  P)) is the feature gets it from the new person fingerprint image, (F_(i DB)) is any
feature gets it from the database.
According to Eq. (12):
If the rate of F ≥ 80%, then F_(i  P) is same of one feature in DB, else
If the result is more than one fingerprint image features have same rate value (ie. More
than one is bigger of 80%), then: the maximum value is the nearest features back in to
unknown person fingerprint image.
Identification: from Steps 3 and 4, the new unknown inked fingerprint image is: Accept or
Reject.
```

4. RESULTS AND DISCUSSION

Approximately 51 inked fingerprints were extracted and stored with data for shape features of that fingerprint pattern. In the experimentation of the identification phase, 21 inked fingerprint images were inserted. Fingerprint Features Databases system is the first step in this work and the task to extract the shape features from inked fingerprint image after rotating it then stored in the databases system in one of local database (DB0, DB1, and DB2). In the identification step, the data will be compared with the specification of the inked fingerprint image and what had been extracted based on the methods that were represented and described of the part of the moments, considering the features that were stored in images databases. The experiment is calculated under the following conditions:

1. Inked fingerprint on paper is used only (offline)
2. All fingerprints for any user have same ink color
3. All of the test images have the same size and resolution from ink paper scanning

Images system contains 17 fingerprint images for 17 persons, each person has 3 kinds of and saving their features after rotation step into local database (DB0, DB1, and DB2) that means the finally 51 images stored in databases system. Figure 3 shows the result of preprocessing steps from algorithm (1) for inked fingerprint input image, such as gray scale image, smoothing, threshold segment, and thinning.

Table 1 included all the information of features for the test *Person11* fingerprint image, from fingerprint features system using Algorithm (1). Figure 4 shows the results of this image when it rotates about 33-degree, 69-degree and 106-degree, saved in DB0, DB1, and DB2 sequentially. When compute F in (12), the value of F is different between origin image and each of rotate state for same *Person11* image according on angle degree. It is clear that rotation about 0-45^{o} is nearest function value of an origin fingerprint image where F=97.36.

Table1. Information of features for *Person11* fingerprint

Moment Features	Origin	D1(0-45)	D2(45-90)	D3(90-180)
∂-1	0.301	0.272	0.222	0.516
∂-2	0.772	0.794	0.719	1.103
∂-3	0.989	1.793	1.675	2.251
∂-4	1.521	1.541	1.413	2.180
∂-5	3.097	3.209	2.957	4.397
∂-6	2.106	1.938	1.773	2.732
∂-7	0.502	0.292	1.313	1.800
F		97.361721	95.87511	59.610517

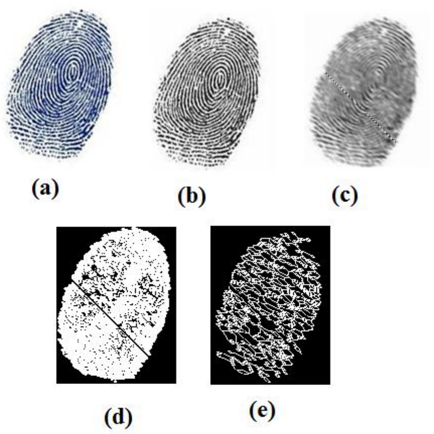

Figure 3. Preprocessing steps, (a) inked fingerprint, (b) gray scale image, (c) smoothing, (d) threshold segment, (e) thinning

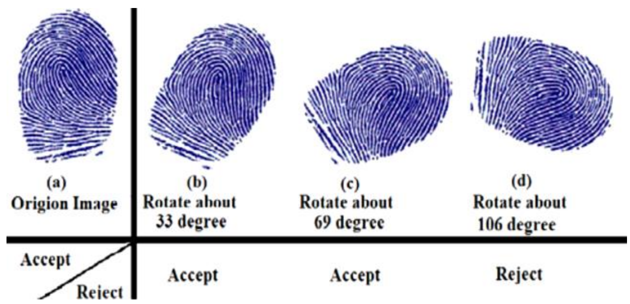

Figure 4. The identification result for person11 fingerprint and its rotation states

A new unknown fingerprint image is for *Person18* for recognition it within database images. After we find the features moment for *Person18* fingerprint image test input. The comparing between 7 features with 51 fingerprint image features is saved in the database (each local database has 17 image). Figure 5 include compare chart and table content the features for new input image *Person18* and 7 features for each rotate case for *Person03*, *Person14*, and *Person10* fingerprint shape features will be saved in three local databases.

In the state of image *Person18* in Figure 5, and Table 2 shows the identification result, it's clear that *Person14*'s rate features of the input image is equal to 79.965 and it has been rejected, like images of the fact that the comparison rate was less than 80% the requirement proposed in the discrimination step 4 from Algorithm 2. Noticed that the features of this input image is approaching the features of a single image stored in the database DB0 named *Person10* more than others by 99.422 ratio, which was rotated at an angle of 35 degrees on the original image, while the ratio of the next it goes back to the forms *Person03* and stored in the database DB1 which been rotated 68 degrees angle for original image and the rate features of the input image is equal to 84.421, according of the condition in Algorithm 2, the result have more than one fingerprint image features bigger of 80%, so the maximum value is the nearest features back in to unknown person fingerprint image that for *Person10*.

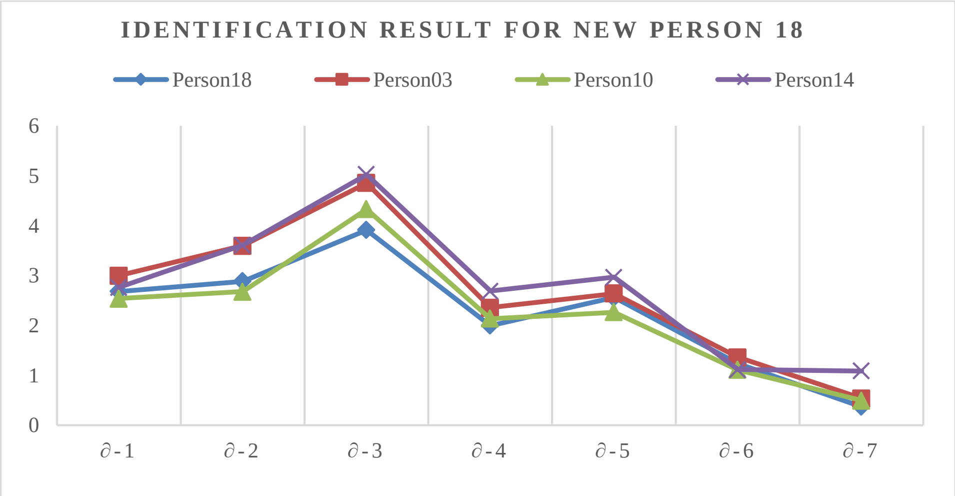

Figure 5. Recognition step for fingerprint image *Person18* features

Table 2. Feature ratio condition for *Person18* identification

	Person18	*Person03*	*Person10*	*Person14*
∂-1	2.677	2.996	2.536	2.761
∂-2	2.884	3.592	2.675	3.605
∂-3	3.911	4.852	4.328	5.023
∂-4	1.994	2.355	2.132	2.683
∂-5	2.555	2.635	2.261	2.963
∂-6	1.229	1.356	1.103	1.109
∂-7	0.366	0.533	0.491	1.083
F		84.42120	99.422147	79.965857

5. CONCLUSION

In this research the aim was to rely on the features of the ridges shape of a fingerprint being different between humans. In features extraction, relied on moments to extract the features of the shape of the fingerprint, and because the approved fingerprint type was ink on paper, then took into account that the printed fingerprints vary in terms of the location of fingerprint on paper, therefore the fingerprint image was rotated at one angle Ranges (0-45) (45-90) and (90-180) and extracted these features again and stored them in a local database (DB0, DB, and DB2). It is not necessary to find all fingerprint-derived vertical alignment on a regular basis, so we proposed fingerprint by processed rotation in the order of several states and the extent of each case. In the experimental fingerprint identification system, the fingerprint image for unknown person is used as input and compared with 51 features of the persons fingerprint images previously stored in the system's local databases by the similarity function in step 3 of Algorithm (2). More values of the angle degree of image rotation of the fingerprint are funded, the less the rate image recognition, and the images of inked fingerprint on paper is more difficult to separate the fingerprint image quality from the intrinsic finger quality.

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REFERENCES

[1] Z. Huang and J. Leng, "Analysis of Hu's moment invariants on image scaling and rotation," in *2010 2nd International Conference on Computer Engineering and Technology*, 2010, vol. 7, pp. V7-476-V7-480, doi: 10.1109/ICCET.2010.5485542.

[2] S. A. Daramola and C. N. Nwankwo, "Algorithm for fingerprint verification system," *J. Emerg. Trends Eng. Appl. Sci.*, vol. 2, no. 2, pp. 355–359, 2011.

[3] P. Assiroj, H. L. H. S. Warnars, E. Abdurrachman, A. I. Kistijantoro, and A. Doucet, "Measuring memetic algorithm performance on image fingerprints dataset," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 19, no. 1, pp. 96–104, 2021, doi: 10.12928/TELKOMNIKA.V19I1.16418.

[4] E. Yosrita, R. N. Aziza, R. F. Ningrum, and G. Muhammad, "Denoising of EEG signal based on word imagination using ICA for artifact and noise removal on unspoken speech," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 22, no. 1, pp. 83–88, 2021, doi: 10.11591/ijeecs.v21.i4.pp83-88.

[5] F. F. Alkhalid, A. M. Hasan, and A. A. Alhamady, "Improving radiographic image contrast using multi layers of histogram equalization technique," *IAES Int. J. Artif. Intell.*, vol. 10, no. 1, pp. 151–156, 2021, doi: 10.11591/ijai.v10.i1.pp151-156.

[6] Q. A. Al-hussain Hadi, "Vein palm recognition model using fusion of features," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 18, no. 6, pp. 2921–2927, 2020, doi: 10.12928/TELKOMNIKA.v18i6.16149.

[7] M. El Beqqal, M. Azizi, and J. L. Lanet, "Multimodal access control system combining RFID, fingerprint and facial recognition," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 20, no. 1, pp. 405–413, 2020, doi: 10.11591/ijeecs.v20.i1.pp405-413.

[8] K. Djunaidi, H. B. Agtriadi, D. Kuswardani, and Y. S. Purwanto, "Gray level co-occurrence matrix feature extraction and histogram in breast cancer classification with ultrasonographic imagery," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 22, no. 2, pp. 187–192, 2020, doi: 10.11591/ijeecs.v22.i2.pp187-192.

[9] V. Jaiswal, V. Sharma, and S. Varma, "An implementation of novel genetic based clustering algorithm for color image segmentation," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 3, pp. 1461–1467, 2019, doi: 10.12928/TELKOMNIKA.v17i3.10072.

[10] M. Oktiana, F. Arnia, Y. Away, and K. Munadi, "Features for cross spectral image matching: A survey," *Bull. Electr. Eng. Informatics*, vol. 7, no. 4, pp. 552–560, 2018, doi: 10.11591/eei.v7i4.843.

[11] M. A. Rajab and L. E. George, "An efficient method for stamps recognition using Haar wavelet sub-bands," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 19, no. 3, pp. 792–800, 2021, doi: 10.12928/TELKOMNIKA.v19i3.18763.

[12] A. M. Ibrahim, A. K. Eesee, and R. R. O. Al-Nima, "Deep fingerprint classification network," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 19, no. 3, pp. 893–901, 2021, doi: 10.12928/TELKOMNIKA.v19i3.18771.

[13] T.-S. Nguyen and P.-H. Vo, "Reversible image authentication scheme based on prediction error expansion," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 1, pp. 253–262, 2021, doi: 10.11591/ijeecs.v21.i1.pp253-262.

[14] M. J. Alam and T. M. ShahzahanAli, "A smart login system using face detection and recognition by ORB algorithm," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 20, no. 2, pp. 1078–1087, 2020, doi: 10.11591/ijeecs.v20.i2.pp1078-1087.

[15] D. Madhavi, K. M. C. Mohammed, N. Jyothi, and M. Ramesh Patnaik, "A hybrid content based image retrieval system using log-gabor filter banks," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 1, pp. 237–244, 2019, doi: 10.11591/ijece.v9i1.pp237-244.

[16] T. H. Mandeel, M. I. Ahmad, and S. A. Anwar, "A multi-instance multi-sample palmprint identification system," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 13, no. 2, pp. 825–830, 2019, doi: 10.11591/ijeecs.v13.i2.pp825-830.

[17] C. Hemalatha and E. Logashanmugam, "Analysis of different m-band wavelet filters for face recognition using nearest neighbor classifier," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 12, no. 2, pp. 824–831, 2018, doi: 10.11591/ijeecs.v12.i2.pp824-831.

[18] W. A. Jbara, "Ear biometric verification approach based on morphological and geometric invariants," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 20, no. 3, pp. 1479–1484, 2020, doi: 10.11591/ijeecs.v20.i3.pp1479-1484.

[19] A. M. Alenezi, S. H. Sapar, and I. S. Rakhimov, "On geometric moment invariants," *Int. J. Pure Appl. Math.*, vol. 120, no. 1, pp. 137–148, 2018.

[20] L. Chaorong, L. I. Jianping, F. U. Bo, and X. Yang, "Fingerprint verification based on DFB and Hu invariant moments," *J. Comput. Inf. Syst.*, vol. 8, no. 4, pp. 1407–1414, 2012.

[21] B. Xiao, Y. Zhang, L. Li, W. Li, and G. Wang, "Explicit Krawtchouk moment invariants for invariant image recognition," *J. Electron. Imaging*, vol. 25, no. 2, p. 23002, Mar. 2016, doi: 10.1117/1.JEI.25.2.023002.

[22] F. Arnia, K. Saddami, and K. Munadi, "Moment invariant-based features for Jawi character recognition," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 3, p. 1711, Jun. 2019, doi: 10.11591/ijece.v9i3.pp1711-1719.

[23] M. Arafah and Q. A. Moghli, "Efficient Image Recognition Technique Using Invariant Moments and Principle Component Analysis," *J. Data Anal. Inf. Process.*, vol. 05, no. 01, pp. 1–10, 2017, doi: 10.4236/jdaip.2017.51001.
[24] R. Usha and K. Perumal, "A modified fractal texture image analysis based on grayscale morphology for multi-model views in MR Brain," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 21, no. 1. pp. 154–163, 2021, doi: 10.11591/ijeecs.v21.i1.pp154-163.
[25] P. S. Prasad, B. Sunitha Devi, M. Janga Reddy, and V. K. Gunjan, "A Survey of Fingerprint Recognition Systems and Their Applications," in *International Conference on Communications and Cyber Physical Engineering 2018*, 2019, pp. 513–520, doi: 10.1007/978-981-13-0212-1_53.
[26] P. Assiroj, H. L. H. S. Warnars, E. Abdurachman, A. I. Kistijantoro, and A. Doucet, "The influence of data size on a high-performance computing memetic algorithm in fingerprint dataset," *Bull. Electr. Eng. Informatics*, vol. 10, no. 4, pp. 2110–2118, 2021, doi: 10.11591/EEI.V10I4.2760.
[27] N. A. Hussein and M. M. Fayyadh, "Real-time monitoring of clinic risks using an integrated RFID-FA scheme," *Bull. Electr. Eng. Informatics*, vol. 10, no. 2, pp. 999–1007, 2021, doi: 10.11591/eei.v10i2.2365.
[28] K. Okokpujie, J. Abubakar, S. John, E. Noma-Osaghae, C. Ndujiuba, and I. P. Okokpujie, "A secured automated bimodal biometric electronic voting system," *IAES Int. J. Artif. Intell.*, vol. 10, no. 1, pp. 1–8, 2021, doi: 10.11591/ijai.v10.i1.pp1-8.
[29] E. A. Abed, R. J. Mohammed, and D. T. Shihab, "Intelligent multimodal identification system based on local feature fusion between iris and finger vein," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 1, pp. 224–232, 2021, doi: 10.11591/ijeecs.v21.i1.pp224-232.
[30] F. F. Alkhalid, "The effect of optimizers in fingerprint classification model utilizing deep learning," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 20, no. 2, pp. 1098–1102, 2020, doi: 10.11591/ijeecs.v20.i2.pp1098-1102.
[31] T. M. Shashidhar and K. B. Ramesh, "Novel framework for optimized digital forensic for mitigating complex image attacks," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 5, pp. 5198–5207, 2020, doi: 10.11591/IJECE.V10I5.PP5198-5207.
[32] H. S. Anupama, M. Anusha, A. Joshi, N. Apoorva, N. K. Cauvery, and G. M. Lingaraju, "Security solutions using brain signals," *IAES Int. J. Artif. Intell.*, vol. 7, no. 2, pp. 105–110, 2018, doi: 10.11591/ijai.v7.i2.pp105-110.
[33] M. Magdin, S. Koprda, and L. Ferenczy, "Biometrics authentication of fingerprint with using fingerprint reader and microcontroller Arduino," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 16, no. 2, pp. 755–765, 2018, doi: 10.12928/TELKOMNIKA.v16i2.7572.
[34] S. R. Borra, G. J. Reddy, and E. S. Reddy, "An efficient fingerprint identification using neural network and BAT algorithm," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 2, pp. 1194–1213, 2018, doi: 10.11591/ijece.v8i2.pp1194-1213.
[35] T. Sabhanayagam, V. P. Venkatesan, and K. Senthamaraikannan, "A comprehensive survey on various biometric systems," *Int. J. Appl. Eng. Res.*, vol. 13, no. 5, pp. 2276–2297, 2018.
[36] P. Schuch, "Survey on features for fingerprint indexing," *IET Biometrics*, vol. 8, no. 1, pp. 1–13, Jan. 2019, doi: 10.1049/iet-bmt.2017.0279.
[37] E. A. Raheem, S. M. S. Ahmad, and W. A. W. Adnan, "Insight on face liveness detection: A systematic literature review," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 6, pp. 5165–5175, 2019, doi: 10.11591/ijece.v9i6.pp5165-5175.
[38] M. S. Fairuz, M. H. Habaebi, and E. M. A. Elsheikh, "Pre-trained based CNN model to identify finger vein," *Bull. Electr. Eng. Informatics*, vol. 8, no. 3, pp. 855–862, 2019, doi: 10.11591/eei.v8i3.1505.
[39] A. Akoushideh and M. Modabernia, "CFS: An effective statistical texture descriptor," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 19, no. 1, pp. 553–562, 2020, doi: 10.11591/ijeecs.v19.i1.pp553-562.
[40] K. Okokpujie, S. John, C. Ndujiuba, J. A. Badejo, and E. Noma-Osaghae, "An improved age invariant face recognition using data augmentation," *Bull. Electr. Eng. Informatics*, vol. 10, no. 1, pp. 179–191, 2021, doi: 10.11591/eei.v10i1.2356.
[41] S. W. Chin, K. G. Tay, C. C. Chew, A. Huong, and R. A. Rahim, "Dorsal hand vein authentication system using artificial neural network," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 3, pp. 1837–1846, 2021, doi: 10.11591/ijeecs.v21.i3.pp1837-1846.
[42] S. Cheng, I. Kotsia, M. Pantic, and S. Zafeiriou, "4DFAB: A Large Scale 4D Database for Facial Expression Analysis and Biometric Applications," in *2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition*, Jun. 2018, pp. 5117–5126, doi: 10.1109/CVPR.2018.00537.
[43] Y. Pratama, L. M. Ginting, E. H. L. Nainggolan, and A. E. Rismanda, "Face recognition for presence system by using residual networks-50 architecture," *Int. J. Electr. Comput. Eng.*, vol. 11, no. 6, pp. 5488–5496, 2021, doi: 10.11591/ijece.v11i6.pp5488-5496.
[44] H. H. M. Al Karaawi, M. Q. Dhahir, and I. A. Alamer, "Development modeling methods of analysis and synthesis of fingerprint deformations images," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 6, pp. 6053–6060, 2020, doi: 10.11591/ijece.v10i6.pp6053-6060.
[45] M. A. Elshahed, "Personal identity verification based ECG biometric using non-fiducial features," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 3, pp. 3007–3013, 2020, doi: 10.11591/ijece.v10i3.pp3007-3013.
[46] D. M. Sulaiman, A. M. Abdulazeez, and H. Haron, "Double stages of feature extarction-based GFPMI for colored finger vein identification," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 18, no. 2, pp. 927–937, 2020, doi: 10.11591/ijeecs.v18.i2.pp927-937.
[47] M. T. S. Al-Kaltakchi, H. A. Al-Raheem Taha, M. A. Shehab, and M. A. M. Abdullah, "Comparison of feature extraction and normalization methods for speaker recognition using grid-audiovisual database," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 18, no. 2, pp. 782–789, 2020, doi: 10.11591/ijeecs.v18.i2.pp782-789.

[48] A. H. Alhilali, N. S. Ali, M. F. Kadhim, B. Al-Sadawi, and H. Alsharqi, "Multi-objective attendance and management information system using computer application in industry strip," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 16, no. 1, pp. 371–381, 2019, doi: 10.11591/ijeecs.v16.i1.pp371-381.

[49] H. H. Abbas, A. A. Altameemi, and H. R. Farhan, "Biological landmark vs quasi-landmarks for 3D face recognition and gender classification," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 5, pp. 4069–4076, 2019, doi: 10.11591/ijece.v9i5.pp4069-4076.

[50] T. Sridevi, P. Mallikarjuna Rao, and P. V Ramaraju, "Wireless sensor data mining for e-commerce applications," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 14, no. 1, pp. 462–470, 2019, doi: 10.11591/ijeecs.v14.i1.pp462-470.

[51] T. Mehraj, M. A. Sheheryar, S. A. Lone, and A. H. Mir, "A critical insight into the identity authentication systems on smartphones," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 13, no. 3, pp. 982–989, 2019, doi: 10.11591/ijeecs.v13.i3.pp982-989.

[52] R. A. J. M. Gining, S. S. M. Fauzi, I. M. Ayub, M. N. F. Jamaluddin, I. Puspitasari, and Okfalisa, "Design and development of activity attendance monitoring system based on RFID," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 17, no. 1, pp. 500–507, 2019, doi: 10.11591/ijeecs.v17.i1.pp500-507.

[53] A. A. Alahmadi, "Developing a wireless real-time automated home approach utilizing NI MyRIO microcontroller board and LabVIEW platform," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 16, no. 3, pp. 1273–1278, 2019, doi: 10.11591/ijeecs.v16.i3.pp1273-1278.

[54] O. A. Akinola, S. O. Olopade, and A. S. Afolabi, "Development of mobile and desktop applications for a fingerprint-based attendance management system," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 24, no. 1, pp. 570–580, 2021, doi: 10.11591/ijeecs.v24.i1.pp570-580.

[55] P. S. Sanjekar and J. B. Patil, "Multimodal biometrics with serial, parallel and hierarchical mode at decision level fusion," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 16, no. 3, pp. 1303–1310, 2019, doi: 10.11591/ijeecs.v16.i3.pp1303-1310.

[56] D. Eridani, E. D. Widianto, I. P. Windasari, W. B. Bawono, and N. F. Gunarto, "Internet of things based attendance system design and development in a smart classroom," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 23, no. 3, pp. 1432–1439, 2021, doi: 10.11591/ijeecs.v23.i3.pp1432-1439.

[57] S. Sujana and V. S. K. Reddy, "Comparison of levels and fusion approaches for multimodal biometrics," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 23, no. 2, pp. 791–801, 2021, doi: 10.11591/ijeecs.v23.i2.pp791-801.

[58] K. Okokpujie, E. Noma-Osaghae, S. N. John, C. Ndujiuba, and I. P. Okokpujie, "Comparative analysis of augmented datasets performances of age invariant face recognition models," *Bull. Electr. Eng. Informatics*, vol. 10, no. 3, pp. 1356–1367, 2021, doi: 10.11591/eei.v10i3.3020.

[59] A. M. Alkababji and O. H. Mohammed, "Real time ear recognition using deep learning," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 19, no. 2, pp. 523–530, 2021, doi: 10.12928/TELKOMNIKA.v19i2.18322.

[60] A. B. Channegowda and H. N. Prakash, "Multimodal biometrics of fingerprint and signature recognition using multi-level feature fusion and deep learning techniques," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 22, no. 1, pp. 187–195, 2021, doi: 10.11591/ijeecs.v21.i4.pp187-195.

[61] P. V Kumar and K. M. Jeevan, "Face recognition with frame size reduction and DCT compression using PCA algorithm," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 22, no. 1, pp. 168–178, 2021, doi: 10.11591/ijeecs.v21.i4.pp168-178.

[62] S. Kuila, N. Dhanda, and S. Joardar, "Feature extraction of electrocardiogram signal using machine learning classification," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 6, pp. 6598–6605, 2020, doi: 10.11591/IJECE.V10I6.PP6598-6605.

[63] C. Kommini, S. Asadi, and K. Ellanti, "Scale and Rotation Independent Fingerprint Recognition," *Int. J. Comput. Sci. Inf. Technol.*, vol. 2, no. 4, pp. 1764–1773, 2011.

[64] S. Abdalkafor, "DFRS-database for fingerprint recognition system using Ink-On-Paper technique," *J. Eng. Appl. Sci.*, vol. 13, no. 17, pp. 7401–7407, 2018, doi: 10.36478/jeasci.2018.7401.7407.

[65] K. Cao and A. K. Jain, "Automated Latent Fingerprint Recognition," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 41, no. 4, pp. 788–800, Apr. 2019, doi: 10.1109/TPAMI.2018.2818162.

[66] K. Noor *et al.*, "Performances Enhancement of Fingerprint Recognition System Using Classifiers," *IEEE Access*, vol. 7, pp. 5760–5768, 2019, doi: 10.1109/ACCESS.2018.2879272.

[67] R. J. Martin and Sujatha, "Symbolic-connectionist representational model for optimizing decision making behavior in intelligent systems," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 1, pp. 326–332, 2018, doi: 10.11591/ijece.v8i1.

[68] A. Y. Shdefat, M.-I. Joo, S.-H. Choi, and H.-C. Kim, "Utilizing ECG waveform features as new biometric authentication method," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 2, pp. 658–665, 2018, doi: 10.11591/ijece.v8i2.pp658-665.

[69] S. Singh, "Forensic and automatic speaker recognition system," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 5, pp. 2804–2811, 2018, doi: 10.11591/ijece.v8i5.pp.2804-2811.

[70] S. Shindo, T. Goto, T. Kirishima, and K. Tsuchida, "An optimization of facial feature point detection program by using several types of convolutional neural network," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 16, no. 2, pp. 827–834, 2019, doi: 10.11591/ijeecs.v16.i2.pp827-834.

[71] I. M. Khudher and Y. I. Ibrahim, "Swarm intelligent hyperdization biometric," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 18, no. 1, pp. 385–395, 2019, doi: 10.11591/ijeecs.v18.i1.pp385-395.

[72] S. Sharma, T. Kumar, R. Dhaundiyal, A. K. Mishra, N. Duklan, and A. Maithani, "Improved method for image security based on chaotic-shuffle and chaotic-diffusion algorithms," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 1, pp. 273–280, 2019, doi: 10.11591/ijece.v9i1.pp.273-280.
[73] S. Singh, "The role of speech technology in biometrics, forensics and man-machine interface," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 1, pp. 281–288, 2019, doi: 10.11591/ijece.v9i1.pp.281-288.
[74] P. Marzuki, A. R. Syafeeza, Y. C. Wong, N. A. Hamid, A. Nur Alisa, and M. M. Ibrahim, "A design of license plate recognition system using convolutional neural network," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 3, pp. 2196–2204, 2019, doi: 10.11591/ijece.v9i3.pp2196-2204.
[75] E. M. Cherrat, R. Alaoui, and H. Bouzahir, "Improving of fingerprint segmentation images based on K-means and DBSCAN clustering," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 4, pp. 2425–2432, 2019, doi: 10.11591/ijece.v9i4.pp2425-2432.
[76] M. G. Vargas, F. E. Hoyos, and J. E. Candelo, "Portable and efficient fingerprint authentication system based on a microcontroller," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 4, pp. 2346–2353, 2019, doi: 10.11591/ijece.v9i4.pp2346-2353.
[77] N. Wangkeeree and S. Boonkrong, "Finding a suitable threshold value for an iris-based authentication system," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 5, pp. 3558–3568, 2019, doi: 10.11591/ijece.v9i5.pp3558-3568.
[78] R. Srividya and B. Ramesh, "Implementation of AES using biometric," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 5, pp. 4266–4276, 2019, doi: 10.11591/IJECE.V9I5.PP4266-4276.
[79] R. R. O. Al-Nima, M. Y. Al-Ridha, and F. H. Abdulraheem, "Regenerating face images from multi-spectral palm images using multiple fusion methods," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 6, pp. 3110–3119, 2019, doi: 10.12928/TELKOMNIKA.v17i6.12857.
[80] E. M. Cherrat, R. Alaoui, and H. Bouzahir, "A multimodal biometric identification system based on cascade advanced of fingerprint, fingervein and face images," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 17, no. 3, pp. 1562–1570, 2020, doi: 10.11591/ijeecs.v18.i1.pp1562-1570.
[81] A. M. Al-Ghaili, H. Kasim, M. Othman, and W. Hashim, "QR code based authentication method for IoT applications using three security layers," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 18, no. 4, pp. 2004–2011, 2020, doi: 10.12928/TELKOMNIKA.V18I4.14748.
[82] N. A. M. Ariffin, F. A. Rahim, A. Asmawi, and Z.-A. Ibrahim, "Vulnerabilities detection using attack recognition technique in multi-factor authentication," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 18, no. 4, pp. 1998–2003, 2020, doi: 10.12928/TELKOMNIKA.V18I4.14898.
[83] Z. S. Abduljabbar, Z. J. Ahmed, and N. K. Ibrahim, "Offline signatures matching using haar wavelet subbands," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 18, no. 6, pp. 2903–2910, 2020, doi: 10.12928/TELKOMNIKA.v18i6.17069.
[84] S. H. A. Refish and S. W. Shneen, "E-PAC: Efficient password authentication code based RMPN method and diffie-hellman algorithm," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 19, no. 1, pp. 485–491, 2020, doi: 10.11591/IJEECS.V19.I1.PP485-491.
[85] P. D. Tinh and T. T. N. Mai, "Ensemble learning model for wifi indoor positioning systems," *IAES Int. J. Artif. Intell.*, vol. 10, no. 1, pp. 200–206, 2021, doi: 10.11591/ijai.v10.i1.pp200-206.
[86] N. T. Morallo, "Vehicle tracker system design based on GSM and GPS interface using arduino as platform," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 23, no. 1, pp. 258–264, 2021, doi: 10.11591/ijeecs.v23.i1.pp258-264.
[87] P. Satanasaowapak, W. Kawseewai, S. Promlee, and A. Vilamat, "Residential access control system using QR code and the IoT," *Int. J. Electr. Comput. Eng.*, vol. 11, no. 4, pp. 3267–3274, 2021, doi: 10.11591/ijece.v11i4.pp3267-3274.
[88] C. Kamlaskar and A. Abhyankar, "Multilinear principal component analysis for iris biometric system," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 23, no. 3, pp. 1458–1469, 2021, doi: 10.11591/ijeecs.v23.i3.pp1458-1469.
[89] M. A. Hendrawan, P. Y. Saputra, and C. Rahmad, "Identification of optimum segment in single channel EEG biometric system," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 23, no. 3, pp. 1847–1854, 2021, doi: 10.11591/ijeecs.v23.i3.pp1847-1854.
[90] M. O. Al-Dwairi, A. Y. Hendi, M. S. Soliman, and Z. A. A. Alqadi, "A new method for voice signal features creation," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 5, pp. 4092–4098, 2019, doi: 10.11591/ijece.v9i5.pp4092-4098.
[91] S. A. Nie, G. Sulong, R. Ali, and A. Abel, "The use of least significant bit (LSB) and knight tour algorithm for image steganography of cover image," *Int. J. Electr. Comput. Eng.*, vol. 9, no. 6, pp. 5218–5226, 2019, doi: 10.11591/ijece.v9i6.pp5218-5226.
[92] A. AlQaisi, M. AlTarawneh, Z. A. Alqadi, and A. A. Sharadqah, "Analysis of color image features extraction using texture methods," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 3, pp. 1220–1225, 2019, doi: 10.12928/TELKOMNIKA.V17I3.9922.
[93] A. Al-Rawashdeh and Z. Al-Qadi, "Creating color image features using local contrast method," *Bull. Electr. Eng. Informatics*, vol. 7, no. 3, pp. 367–376, 2018, doi: 10.11591/eei.v7i3.1216.
[94] S. Kadry, V. Rajinikanth, J. Koo, and B.-G. Kang, "Image multi-level-thresholding with Mayfly optimization," *Int. J. Electr. Comput. Eng.*, vol. 11, no. 6, pp. 5420–5429, 2021, doi: 10.11591/ijece.v11i6.pp5420-5429.
[95] G. K. Ijemaru *et al.*, "Image processing system using matlab-based analytics," *Bull. Electr. Eng. Informatics*, vol. 10, no. 5, pp. 2566–2577, 2021, doi: 10.11591/eei.v10i5.3160.
[96] E. W. Abood, Z. A. Abduljabbar, M. A. Al Sibahee, M. A. Hussain, and Z. A. Hussien, "Securing audio transmission based on encoding and steganography," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 22, no. 3, pp. 1777–1786, 2021, doi: 10.11591/ijeecs.v22.i3.pp1777-1786.

[97] G. M. J. Qaryouti and T. M. Younes, “A flexible method to create wave file features,” *Int. J. Electr. Comput. Eng.*, vol. 11, no. 2, pp. 1311–1318, 2021, doi: 10.11591/ijece.v11i2.pp1311-1318.
[98] M. O. Dwairi, “A modified symmetric local binary pattern for image features extraction,” *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 18, no. 3, pp. 1224–1228, 2020, doi: 10.12928/TELKOMNIKA.v18i3.14256.
[99] F. H. MohammedSediq Al-Kadei, “Two-level hiding an encrypted image,” *Indones. J. Electr. Eng. Comput. Sci.*, vol. 18, no. 2, pp. 961–969, 2020, doi: 10.11591/ijeecs.v18.i2.pp961-969.
[100] K. Soumia, B. Mohammed, H. Aymen, and K. Ibrahim, “Biometric authentication using curvelet transform,” *Indones. J. Electr. Eng. Comput. Sci.*, vol. 20, no. 3, pp. 1332–1341, 2020, doi: 10.11591/ijeecs.v20.i3.pp1332-1341.
[101] J. Chaki and N. Dey, *A beginner’s guide to image shape feature extraction techniques*. CRC Press, 2019.
[102] P. K. Bose and M. J. Kabir, “Fingerprint: A Unique and Reliable Method for Identification,” *J. Enam Med. Coll.*, vol. 7, no. 1, pp. 29–34, Jan. 2017, doi: 10.3329/jemc.v7i1.30748.
[103] M. Hawthorne, *Fingerprints: analysis and understanding*. CRC Press, 2017.
[104] J. E. Albus *et al.*, *Syntactic pattern recognition, applications*, vol. 14. Springer Science & Business Media, 2012.
[105] K. M. Hosny and M. M. Darwish, “Feature Extraction of Color Images Using Quaternion Moments,” in *Recent Advances in Computer Vision*, Springer, 2019, pp. 141–167.
[106] T. Kuremoto, T. Otani, M. Obayashi, K. Kobayashi, and S. Mabu, “A hand shape instruction recognition and learning system using growing SOM with asymmetric neighborhood function,” *Neurocomputing*, vol. 188, pp. 31–41, May 2016, doi: 10.1016/j.neucom.2014.10.108.
[107] J. C. Russ and J. C. Russ, *Introduction to image processing and analysis*. CRC press, 2017.
[108] M. Sorapure, “Text, Image, Data, Interaction: Understanding Information Visualization,” *Comput. Compos.*, vol. 54, p. 102519, Dec. 2019, doi: 10.1016/j.compcom.2019.102519.
[109] O. A. Hammood *et al.*, “An effective transmit packet coding with trust-based relay nodes in VANETs,” *Bull. Electr. Eng. Informatics*, vol. 9, no. 2, pp. 685–697, Apr. 2020, doi: 10.11591/eei.v9i2.1653.
[110] H. R. Ibraheem, Z. F. Hussain, S. M. Ali, M. Aljanabi, M. A. Mohammed, and T. Sutikno, “A new model for large dataset dimensionality reduction based on teaching learning-based optimization and logistic regression,” *TELKOMNIKA (Telecommunication Comput. Electron. Control.*, vol. 18, no. 3, p. 1688, Jun. 2020, doi: 10.12928/telkomnika.v18i3.13764.
[111] M. A. Mohammed, A. A. Kamil, R. A. Hasan, and N. Tapus, “An Effective Context Sensitive Offloading System for Mobile Cloud Environments using Support Value-based Classification,” *Scalable Comput. Pract. Exp.*, vol. 20, no. 4, pp. 687–698, Dec. 2019, doi: 10.12694/scpe.v20i4.1570.
[112] M. A. Mohammed, I. A. Mohammed, R. A. Hasan, N. Tapus, A. H. Ali, and O. A. Hammood, “Green Energy Sources: Issues and Challenges,” in *2019 18th RoEduNet Conference: Networking in Education and Research (RoEduNet)*, Oct. 2019, pp. 1–8, doi: 10.1109/ROEDUNET.2019.8909595.
[113] N. Q. Mohammed, M. S. Ahmed, M. A. Mohammed, O. A. Hammood, H. A. N. Alshara, and A. A. Kamil, “Comparative Analysis between Solar and Wind Turbine Energy Sources in IoT Based on Economical and Efficiency Considerations,” in *2019 22nd International Conference on Control Systems and Computer Science (CSCS)*, May 2019, pp. 448–452, doi: 10.1109/CSCS.2019.00082.
[114] Z. H. Salih, G. T. Hasan, M. A. Mohammed, M. A. S. Klib, A. H. Ali, and R. A. Ibrahim, “Study the Effect of Integrating the Solar Energy Source on Stability of Electrical Distribution System,” in *2019 22nd International Conference on Control Systems and Computer Science (CSCS)*, May 2019, pp. 443–447, doi: 10.1109/CSCS.2019.00081.
[115] N. D. Zaki, N. Y. Hashim, Y. M. Mohialden, M. A. Mohammed, T. Sutikno, and A. H. Ali, “A real-time big data sentiment analysis for iraqi tweets using spark streaming,” *Bull. Electr. Eng. Informatics*, vol. 9, no. 4, pp. 1411–1419, Aug. 2020, doi: 10.11591/eei.v9i4.1897.