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HYBRID HAND-DIRECTIONAL GESTURES FOR BAIOMETRIC BASED ON AREA FEATURE EXTRACTION AND EXPERT SYSTEM

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ABSTRACT

Nowadays, biometric authentication researches are becoming one of the major focuses among researchers due to various fraud attempts are taking place. Although, several authentication operations are available, these are not free of defects that affect negatively on the authentication operation. Therefore, a novel technique is proposed using index-finger of a hand in order to point out random directions such as up, down, left, or right. Accordingly, a new feature extraction based on area of the index-finger is proposed. It is hybrid between static and dynamic hand directional gesture recognition having advantage that is not forgettable as password due to biologically that this gesture is stored in the brain as visual memory type. This method starts by recording a video around 2-10 seconds as time duration, and then frames are processed one by one to output 4-set-direction, which are deemed as passwords for an individual. Later on, extracted gesture direction vector is matched against the stored one, to output either "accept" or "reject" status. Experiments were conducted on 60-video frames were prepared for training and testing recorded from 10 individuals. Result findings demonstrate high successful recognition rate as the performance accuracy is 98.4% of this proposed method.

Keywords: *Biometrics, Hand Gesture, Pattern Recognition, Feature Extraction, Expert System, Computer Vision, Data Science.*

1. INTRODUCTION

User authentication is one of the commonly used mechanisms of information security. Authentication operation can be described as following, either something you know, something you have or something you are [1-3]. The first mode relies on the knowledge factors such as a password, Personal Identification Number (PIN). The second mode refers to any object possession for the user such as smartcards, and keys. The third one is biometric authentications that are based on physical and / or behavioral characteristics of an individual such as fingerprint, retinal pattern, DNA, signature, face, voice, gesture [4, 5]. The first two modes have their limitations. For example, password can be guessed, forgotten, or cracked through dictionary or brute force attack, whereas smartcards are at risk of being lost, shared, stolen or duplicated. However, biometric can overcome the aforementioned limitations but still is not free of defects.

The word biometrics is derived from two Greek words, which are bio meaning "life" and metron meaning "measure" [6]. Biometrics falls into two types; biological such as fingerprint face, palm, iris, which usually this type of biometrics cannot be altered without causing trauma or pain to individuals [7]. The second category is behavioral based biometrics such as a signature (on-line or off-line), gait, voice, keystrokes and gesture. Behavioral based biometrics are attributes that are acquired by individuals and stabilized after a period of time [3, 8]. Ideal biometrics should satisfy a number of desirable properties as follows: it needs to be universal to cover as many individuals as

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possible. Uniqueness of biometrics traits is equally important to easily differentiate between different individuals. In addition, an ideal biometrics should be based on permanent characteristics, which are easily collectable from users [9]. In a biometrics system, a template should be stored in a database during enrolment phase as a user's reference model. Raw templates can reveal partial or complete information regarding the user biometrics data, which remains a threat to the security of the system [3]. Thus, it is essential to protect biometrics templates, similar to the password counterparts. Gestures is kind of communication among humans. In fact, gesturing is a movement of a human body, especially of hands and face that show a notion or feeling something said or done [10]. It is deeply rooted in our communication that people often continue gesturing when speaking on the telephone. Human gesture could be by face, body or hand gesture [10, 11]. Human being hand gesture is dedicated in this research paper. All information about gesture recognition and taxonomy are described in [10]. Hand gesture is deemed as a non-invasive biometric [12].

Normal people authentication is done by using password, which has a defect as it is difficult to be kept or it might be forgotten especially by elderly people. Biometric has overcome this problem but it is still has its own problems, i.e., for fingerprint, palm-print and signature, in where the devices might be infected with specific diseases, hence, virus may be distributed among the users of these tools. Furthermore, the disadvantages of these tools and devices might be symptom to cause allergies to the users [13]. Accordingly, what is the safest method of doing authentication without aforementioned obstacles?, it is by using vision-based devices such as face or iris recognition devices, but these still having problem as some people object to store their faces inside databases due to their privacies. Ultimately, to solve the people authentication as free of all aforementioned obstacles, hand gesture recognition is the solution. Furthermore, hand gesture authentication is useful of facilitating the authentication operation for the blind people. The novelty of the proposed technique is using index-finger of a hand to point out to random different directions, accordingly, new feature extraction based on pixel-object area technique is proposed. However, one of the major challenges in vision-based hand gesture recognition is to recognize the hand gestures effectively in different background conditions. Background may vary from place to another depending on the environment conditions. Background conditions change due to varying illumination conditions, occlusion, dynamic or moving objects in background, cluttered or distorted objects in background scene etc. In designing the real time recognition system, these conditions should be taken into consideration as these challenges present in real time scenario, which affects the robustness of the system in recognizing the hand gestures [10]. Regarding to the proposed biometric, some people feel that long sequences of directional gestures will become hard to remember (as limitation), while short ones will be very easy to copy. However, aforementioned obstacles as hard remembering and easy to copy are the same as the normal credential security so called password, but the proposed technique outperforms password in terms of simplicity using styles as vision-based control (gesture) compared to touch-based control (password). The scope of this research is as following, it is fixed background of the individual to gain fast processing, as well as it is considered as indoor signing operation, to be invariant to the weather changing. This paper aims to introduce an efficient algorithm to verify human being according to their several hand-direction-gesture captured by time temporal frames (video), it is a hybrid operation between static and dynamic hand gesture recognition as the recognition depends on both of hand style (static) and time temporal (dynamic) having advantage as it is not forgettable as password due to biologically this gesture is stored in the brain as visual memory type that is the most powerful memory type of human brain. The recognition is based on forefinger (index-finger) direction of that video.

The organization of the paper is as follows; Section II covers literature review regarding overall hand gesture previous works and types, Section III explains the proposed framework and the concept methodology comprises the required features and their classifications. Section IV presents the experiment details of this research, while Section V presents the results and discussions. Finally, Section VI concludes this research and tailing with a possible future work.

2. LITERATURE REVIEW

Human authentication based hand gesture is an application of Hand Gesture Recognition which is available in the literature that can be broadly divided into two types, Touch-Based and Contactless-Based hand gesture. The former is described as giving multi-hand gesture by touching

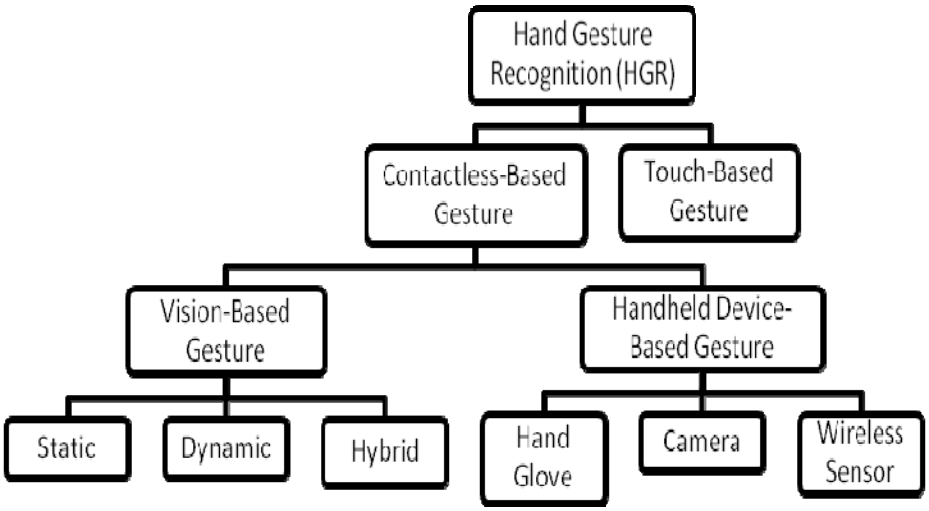

Figure 1. Hand Gesture Types.

hand gesture authentication [15], while the latter one can be characterized as hand gesture signals are transmitted to a computer for recognition operation remotely without any touched device [16-18]. Contactless-based has also two branches. Firstly, handheld device-based hand gesture which employs sensors (mechanical or optical) attached to a human hand that transduces hand waving signals for determining the hand posture or path trajectories. In this method, the user has to carry a load of cables which are connected to the computer and hinders the ease and naturalness of the user interaction, e.g., glove based hand gesture [19]. Secondly, vision-based hand gesture, which is described as a computer understanding the hand gesture through camera or sensors [20], e.g., air-writing characters can be recognized similar to motion gestures in free space by hand [21]. Generally, the vision-based recognition of human hand gesture also falls into three types as being noticed in the literature: statics, which is based on the appearance, geometry and shape of hand per image such as recognizing "ok" sign or "stop" sign etc. [22], for example, a static hand gesture has been recognized by using 52 hand shape features including bones length and width, palm characteristics and relative distance relationships among fingers, palm center and wrist with using SVM and ANN [23], dynamic hand gesture is a sequence of hand shapes with associated spatial transformation features such as rotation, translation, scaling/depth variations etc, that describe the hand trajectories of the movement, it is also can be defined as a spatial-temporal pattern [24] and the basic features can be: velocity, movement shape, location (position), angular speed, and orientation. The motion of the hand can be described as a temporal sequence of points with respect to any point of the hand [25], for example dynamic hand gestures have been recognized by using Leap Motion Controller (LMC) to extract feature vector that will be fed to the Hidden Conditional Neural Field (HCNF) as a classifier [26]. It is worth to mention that dynamic hand gesture recognition needs a real-time processing from frame to frame in a frame sequence of a video. The third type which is hybrid gesture recognition, in this approach, a combination of both static and dynamic gestures is executed in a real-time processing, for example in [27], a real-time recognition algorithm tracks and recognizes hand gestures based on depth data collected by a Kinect sensor is presented. Figure 1 depicts the proposed classification of hand gesture recognition types altogether in one chart.

Precisely, the existing works in the literature are as following, hand gesture has been used to identify human being by using trajectories of hand gesture in air, as features are fed into Dynamic Time Warping (DTW) classifier [12]. In 2002 [28], hand signature made in free space on which the trajectories were collected by using lighting device, the database is named Cyber-SIGN JAPAN, where the ERR is reported to be 7.8%. In the work by Piekarczyk [29], besides using coordinate x and y signals, velocity signal is used for gaining a better feature representation, after that combination of DCT and DTW as classifier, the result in FAR & FRR is 0 with 50 users. In 2015, trajectory curve shape by using shape descriptor to extract the view-invariant features of a three dimensional (3D) trajectory is done. Steps of this work are pre-processing, shape feature extraction, orientation feature extraction and ends with classification as DTW. The result is reported as deriving confusing

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matrix but without clear accuracy computation [30]. In 2015 in [31], dynamic hand gesture features as 2D-coordinates are extracted from the tracked fingertip. First component was considered in PCA for including the most variance components, the experiment was run on the dataset called SIGAIR, and DTW is used as a classifier where accuracy result is 97.5% taken for only 10 individuals. In 2014 in [32], hand motion trajectories (path) based on DG5VHand glove device also used PCA as feature extraction, and in terms of matching, LDA, K-NN, SVM are used. To sum up, existing works for human being identification based on hand gesture are all depend on the trajectories (path) (x_i , y_i , z_i) extracted from the hand motion between frame and next the frame of the same video as in (1).

$$Path = P(x_i, y_i, z_i) where i = 1,2,3,...T \quad (1)$$

Besides the position features, there is a depth signal which is the third dimension for the features. Normally, this is obtained by using Kinect input devices. No work is available in the state-of-the-art is sufficient in terms of high processing rate, high accuracy and sufficient security. Therefore, the challenge is still open in this framework by improving the recognition rate and the robustness of the hand segmentation (to handle noise). In this paper, a new method of hand gesture recognition for authentication and identification will be presented based on hand direction of the finger. The advantage of this method is accurate in terms of recognition rate, as the output will be a sequence of digitally one of the four directions either left, right, up or down. The procedure is that, each individual keeps his/her specific sequence of direction and then storing it in a database to be used later on as a reference model.

3. METHODOLOGY

The basic idea in this framework is to authenticate an identity based on some hand gestures. Here, the hand gesture specifically is divided into four directions (signals), i.e., left, right, up and down directions (directions detail is explained with the next section). The authentication operation is implemented by recording a video for approximately 5 seconds for an individual. Various direction signals are extracted from the 5 second video, which are originated from the individual then to be predicted into set of signals that are deemed as password for the user. The framework design is depicted in Figure 2.

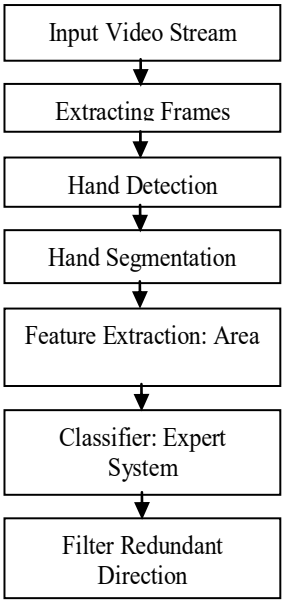

Figure 2. Framework Design Of Hand Direction Gesture.

The operation starts by recording a specific time period of gesture by using Camera, then extracting frames as image in Figure 3(1), then hand detection by using hand colour as YCbCr [33]as image in Figure. 3(2).

Afterward hand segmentation by converting the frame into black and white image, noise removing by using some morphological operations as illustrated in Figure 3(3), and largest object search in order to ensure removing all objects except the hand object as in Figure 3(4). The image, which is in Figure 3(5), is the tracker border around the target hand. Now, the feature vector will be area of the hand object (convex). The classifier will be expert system. Finally, it is essential to add a filter for removing the consecutive redundant directions in order to avoid problem that might be occurred by the individual whether one time gives fast gesture and later on gives the same slow gesture.

In other words, the reason of adding the last block named Filter Redundant Direction in order not to restrict a user to record the same time frame at anytime, as sometimes, individual gives his/her direction gesture within 6 seconds video time duration, and later the same individual gives the same direction gesture but with

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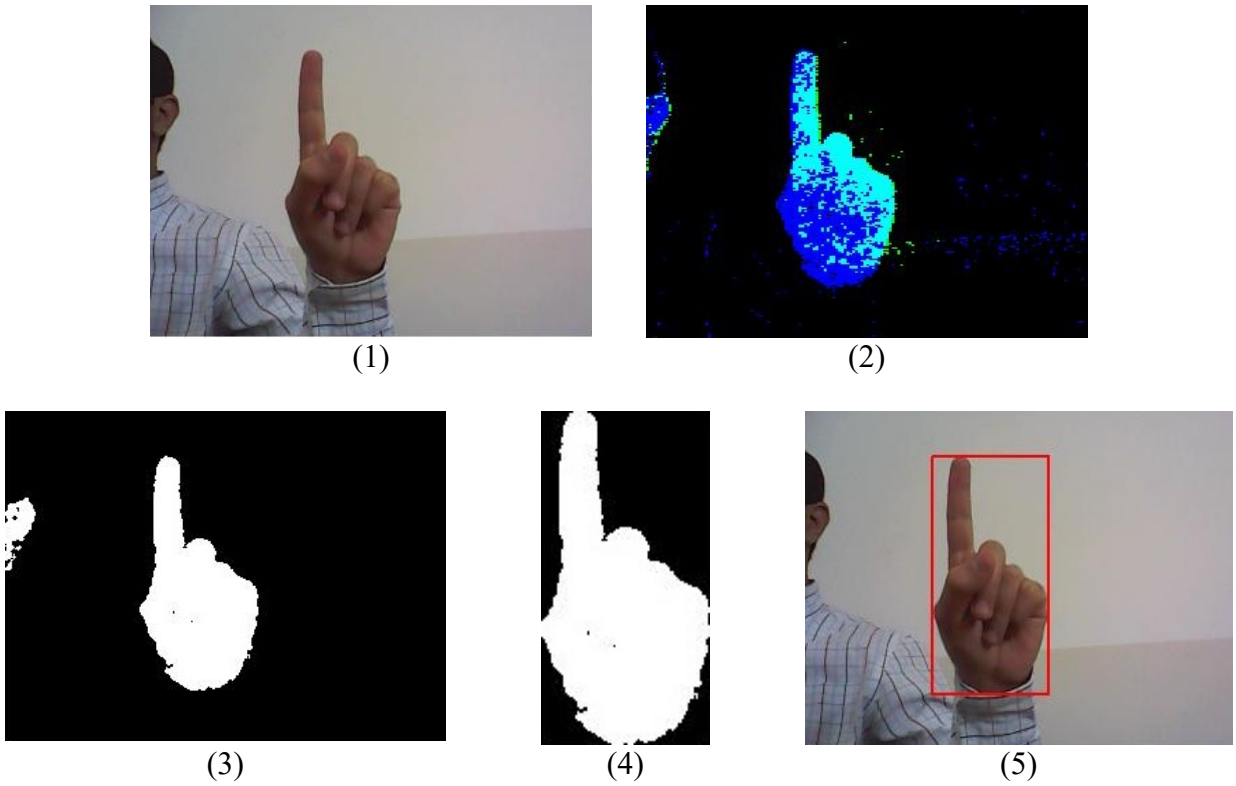

Figure 3. Segmented And Tracked Index- Finger Doing Directional Gesture.

redundant direction is utilized, which is based on discarding the similar consecutive redundant direction gesture. For example, 3fps-video has 4 sec time duration. Before filtering, frame sequence is recorded as follows: *up, up, left, down, down, down, down, left, up, right, right, right*. Now after this filter, frame sequence becomes as following: *up, left, down, left, up, right*. It is worth to mention that each individual will have his/her own or unique direction sequence to be matched against it for the authentication operation. However, in case occasionally two users have the same gesture direction sequence, this will cause problem for the authentication, and this case is considered as the weakness of this idea. Although, it is rarely happening, it is needed to be mentioned in the paper.

3.1 Hand Localization

The operation starts by converting from RGB to YCbCr in order to separate luminance from the chrominance. Here, blue and red chrominance are used to model the hand skin colour. Also, hand detection operation is applied based on filtering *Cb* steps will be converting to the white and black image, afterward median filter, which is replacing each pixel value in an image with the median value of its neighbors, is applied to remove noise, then, searching operation based on pixel numbers is applied for the largest object which is certainly deemed the hand object. Finally, setting the bounding numbers around the hand object (four-point-borders) is applied, according to these bounding points; the real-time tracker lines will be drawn around the ROI.

3.2 Feature Extraction

Features that are used in this research are areas of the hand object, which is divided into two equally parts to compute the Left-Area and Right_Area in case the length of columns is more than rows as shown in Figure 4(1). On the other hand, the features are Upper_area and Lower_area in case length of rows is more than columns as shown in Figure 4(2).

The equation for computing the pixel area is shown in Eq. (1):

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$$Area = \begin{cases} \sum_{y=1}^{m}\sum_{x=1}^{n} pixel(x,y), pixel(x,y) = 1 \\ 0 \quad , pixel(x,y) = 0 \end{cases} \quad (1)$$

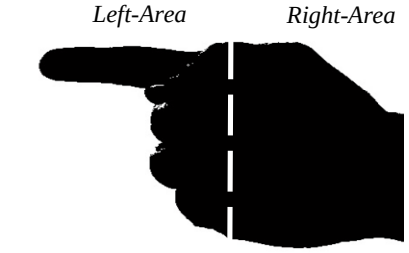

Figure 4(1). Shows left and right area features of hand part.

Where (x, y) are pixel trajectories of the object.

Figure 4(2). Shows Upper And Lower Area Features Of Hand Part.

For simplicity, each direction has been referred to as a code number, i.e., upper direction is referred to 1, lower direction to 2, right direction to 4 and left direction to 3, as shown in Figure 5.

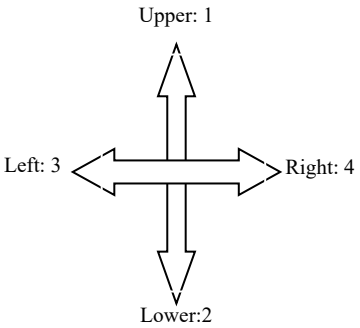

Figure 5. Showing 4-Direction As Code Numbers (1 Till 4).

The method of filtering redundant direction is removing any similar adjacent direction. The following table shows example explains filter redundant direction. This table has directional codes before and after filtering operation, which is the last stage of the processing. As a result, the final directional gestural code is : 1, 2,3,4,1,4,1,4,1.

Table 1 Directional Codes Before And After Filtering Operation.

Before Filtering	1	1	2	3	3	3	4	4	1	1	1	4	1	4	1
After Filtering	1	-	2	3	-	-	4	-	1	-	-	4	1	4	1

3.3 Directional Gesture Classification

After extracting area for each part of the localized hand, expert system [34] is utilized in this research to output the result of each frame direction, the reason of selecting expert system is due to the nature of the feature extraction as an area of the hand as explained in previous sections. Furthermore, this problem of the classification can be modelled explicitly by using if-else as a programming statement. However, this classification type can be resolved using other techniques as such ANN and SVM but it will be more complex. Therefore, expert system has been used which is functioned by setting the knowledge bases which are described as set of rules as If-Then-Else as a programming language statement. Besides the set knowledge base, inference also must be entered to the expert system to be depended on it so as to enable these rules how to make the decision. Inferences here are represented by the features which are in our research the areas of the hand parts (left and right parts or upper and lower part).

Classification for the four signals is described as follows:

1- Direction Left (Left Signal)

As the image depicted in Figure 4(1), if it is assumed that the object is divided into two parts (left half and right half). It is clear that the left object is smaller than the right object part. Accordingly, it is predicted that the hand gesture signal will be left signal.

2- Direction Right (Right Signal)

As the image depicted in Figure 4(1), if it is assumed that the object is divided into two parts (left half and right half). It is clear that the right object is smaller than the left object part. Accordingly, it is predicted that the hand gesture signal will be right signal.

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3- Direction Up (Upper Signal)
As the image depicted in Figure 4(2), if it is assumed that the object is divided into two parts (lower half and upper half). It is clear that the lower object is larger than the upper object part. Accordingly, it is predicted that the hand gesture signal will be upper signal.
4- Direction Down (Down Signal)
As the image depicted in Figure 4(2), if it is assumed that the object is divided into two parts (lower half and upper half). It is clear that the upper object is smaller than the lower object part. Accordingly, it is predicted that the hand gesture signal will be down signal.
The overall algorithm for the direction identification is depicted with the following flow chart as shown in Figure 6.

4. EXPERIMENT

To evaluate the performance of the proposed method, series of experiments have been conducted on the dataset, which has been collected from 10-individual who were asked to simulate their authentication by giving their gesture as a 4-direction (*up, down, left, right*) either clockwise or anti-clockwise with any free random gesture provided that the gesture must be kept with that user for the future reference model. Each individual was asked to give 6-sample of his/her hand direction gesture in separate session within two days to achieve the randomness and validation of the taken dataset. Table 2 describes the integrated dataset briefly.

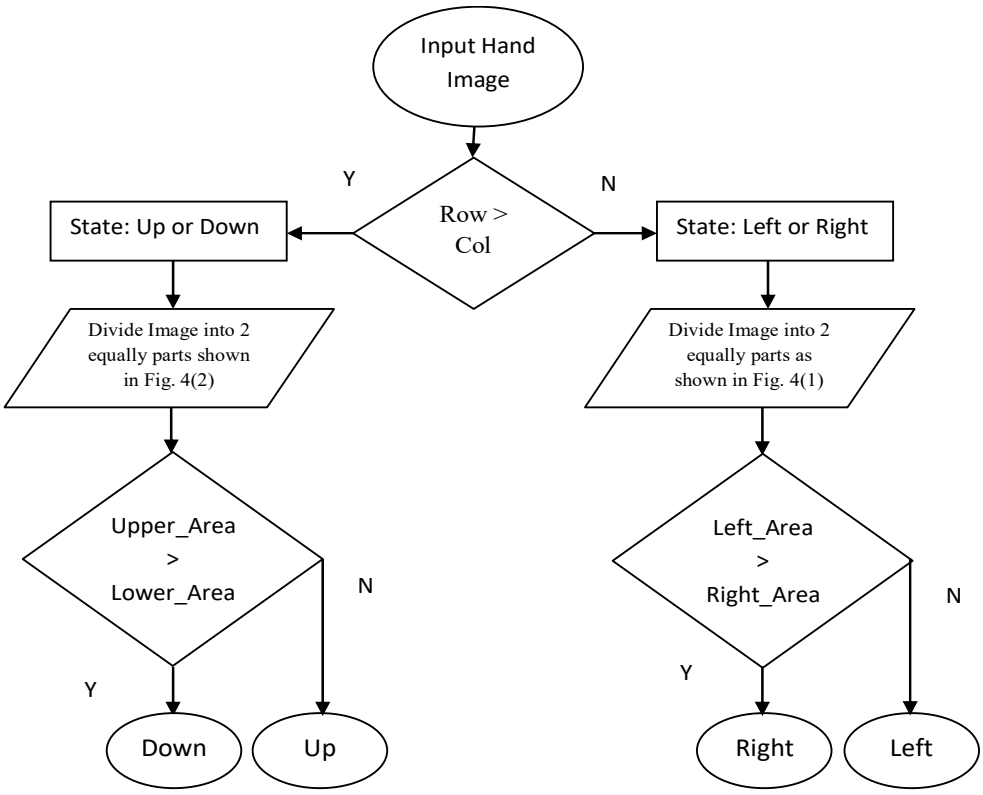

Figure 6. Expert System Classifier Flow Chart

Table 2 Dataset Characteristics.

Number of participants	Sample / participant	Samples No. / Day
10	6	3

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Total number used in this research is 60 video each of which has 15 frames / sec. The time duration of each video is not similar as it is randomly taken ranging from 2 till 5 sec. as overall the proposed algorithm for authentication has tested on more than 2000 frames for both training and testing.

It is worth to mention that the reason for splitting into 2 days for hand direction gesture is to simulate the reality, which is in one day will be for an individual enrolment, later on, with a separated day the same individual will come to give the same gesture for the authentication of an application. The experiment is run by doing training and testing, for training using 3-sample, then store the result direction after filtering (as explained in previous section) in the database as a reference model. Then, a representative vector of gestural code is extracted from the three samples to be ready for matching against testing representative vector which is extracted as the same as training vector. For the verification evaluation both FRR and FAR are used and are calculated from the matching of these two representative vectors. It is essential to mention the characteristics of the hardware, which is used for capturing video recording; its brand is LOGITECH, as a VGA technique, 5MP resolution 70Hz. As well as Matlab R2013a software used with windows 7 operating system installed in a personal computer having core2due, 2GHz CPU and 4G-RAM memory.

5. RESULT AND DISCUSSION

Performance of any verification could be evaluated by two possible errors as follows: False Accept Rate (FAR), which is resulted from the forged templates that are accepted by the computer system falsely during testing and False Rejection Rate (FRR), which is resulted from the genuine template that the system recognizes as the genuine query template wrongly [35]. As overall, the total accuracy of the system is calculated by subtracting the average error rate from 100% as in (2):

$$\text{Accuracy\%} = 100\% - \frac{FAR+FRR}{2} \quad (2)$$

In this research, FAR error does not exist, since there are no forge templates in this experiment. Therefore, FAR is in fact considered to be zero. However, FRR is largely used for the testing measure to assess the recognition rate, because the directional gestural code numbers are considered as genuine templates, if they are wrongly recognized by computer system (test), then the FRR increases. Finally, the equations that are used to estimate the accuracy of the current research are in (3) and (4):

$$\text{Accuracy\%} = 100\% - FRR\% \quad (3)$$

$$FRR\% = \frac{\text{No.of unmatched codes in a vector}}{\text{No.of total code}} \times 100\% \quad (4)$$

Results of first 5 individuals are reported in Table 3 while the other five (6-10) reported in Table 4. Table 3 and 5 have records for directional gesture code for both before and after filtering operation as explained in previous section. Besides that, final representation code is extracted taken after filtering among the 3-sample as labelled with #User-Id, this describes the final row extracted from the three samples after filtering operation, and it is written with #sign and bolded to be recognized well, which will be matched against its counterpart vector code taken from testing part, and accordingly the error as FRR will be calculated to assess the successful accuracy for each user. Furthermore, for each user, as it can be seen that the Final Representation Code Taken after Filtering for both training and testing are similar code exactly, otherwise FRR will be increased according to the degree of the difference between trained and tested vector as shown with the bold vector in table 3.

Filtering operation significantly overcame on the obstacle of the user variant speed of gesture from one time to another. In other words, filtering policy is taking only single flip code and put it in the vector of the sample. For example, in sample-3 of user-10, the preliminary gesture vector output is long with many repetitions code (each frame video will be converted into one code) as:

11111111144222222241111114222222224111111332222223311111113322222222311111111.

After the filtering operation, the result is as: 1 4 2 4 1 4 2 4 1 3 2 3 1 3 2 3 1. It is obvious that the same gesture of code but without redundancy for the digits, or in other words, only flip code has been considered for the feature vector after filtering.

Table 3 Reports Results Of First Three Individuals (1-3) Of This Paper.

User-Id	Sample	Result Code Type	Training Code Gesture	Testing Code Gesture
1	1	Before Filtering	1111111444442233311111444422233111111	1111111111114444444444422233311111111444442222222233311111111111
		After Filtering	142314231	142314231
	2	Before Filtering	1111111444223311114222221111111	1111144422222233331111144444222222231111111
		After Filtering	142314211	142314231
	3	Before Filtering	1111111442233311114233111111111	1111111111111111144444444222222222233333311111111144444422222333333311111111111
		After Filtering	142314231	142314231
#1	**Final Representation Code Taken after Filtering**		**142314231**	**142314231**
2	1	Before Filtering	1111444422222441111114422222241113333331111111	1111144222222224411111111442222224444111113333333311111
		After Filtering	14241424131	14241424131
	2	Before Filtering	1111444422222224111114222224111113333333333111	1111144422222224111111442222222244111133333333331111111
		After Filtering	14241424131	14241424131
	3	Before Filtering	1111442222411114222222224113333331111	111114222224111114222222111333331111
		After Filtering	14241424131	14241421311
#2	**Final Representation Code Taken after Filtering**		**14241424131**	**14241424131**
3	1	Before Filtering	1111111333222244111111111442233111111111	1111111111133332222222444111111111111114422222233111
		After Filtering	13241423131	13241423111
	2	Before Filtering	1111133224411111423311111111	1111111113332222441111111132222233111111111111111
		After Filtering	13241423131	13241323111
	3	Before Filtering	1111113322241111114423111111	1111111111133333332222244111111111144223311111111
		After Filtering	13241423131	13241423111
#3	**Final Representation Code Taken after Filtering**		**13241423131**	**13241423111**

Table 4 Reports Results Of The Three Individuals (4-5) Of This Paper.

4	1	Before Filtering	1111444223111144223311114442223331111111	1111142222333111111444222223111111142223331111
		After Filtering	*1423142314231*	*1423142314231*
	2	Before Filtering	1111144223331111444422223331111444222233311111	1111144442223333111111444222233311444222233
		After Filtering	*1423142314231*	*1423142314231*
	3	Before Filtering	1111142223311114222311233311111	1114423111422331144223311111
		After Filtering	*1423142312311*	*1423142314231*
#4	**Final Representation Code Taken after Filtering**		**1423142314231**	**1423142314231**
5	1	Before Filtering	1111144223111144223111113322411111111	1111111442233111114422233111113224111111
		After Filtering	1423142313241	1423142313241
	2	Before Filtering	1111144222311111422233111113224111111	1111114223111422311113324111111
		After Filtering	1423142313241	1423142313241
	3	Before Filtering	1111144223111111422233111111332241111111	1111142231114223111133224411111
		After Filtering	1423142313241	1423142313241
#5	**Final Representation Code Taken after Filtering**		**1423142313241**	**1423142313241**

Table 5 Reports Results Of The Three Individuals (6-8) Of This Paper.				
6	1	Before Filtering	1111114442331132331144222331111 11	1111144222233311114442233331111 1
		After Filtering	*1423132314231*	*1423142313241*
	2	Before Filtering	1111111142233111144223111142233 111111111111	1111144422222331111422311111422 33111111
		After Filtering	*1423142314231*	*1423142314231*
	3	Before Filtering	1111442233111423111142233111111	1111442231114222311142231111111
		After Filtering	*1423142314231*	*1423142314231*
#6	**Final Representation Code Taken after Filtering**		**1423142314231**	**1423142314231**
7	1	Before Filtering	1111111111111111111442222333331 11111111	111111114222233311144444441111
		After Filtering	*14231*	*1423141*
	2	Before Filtering	1111111111114422223311111144444 44111111111111111	1111114442222233333111111111444 4441111
		After Filtering	*1423141*	*1423141*
	3	Before Filtering	1111111111144422233311144444444 111111111111	111114442222233114444111111
		After Filtering	*1423141*	*1423141*
#7	**Final Representation Code Taken after Filtering**		**1423141**	**1423141**
8	1	Before Filtering	1111113332241132241122241111111	1111133322241133322441111133222 4111111
		After Filtering	*1324132412411*	*1324132413241*
	2	Before Filtering	1111132441132441132441111111	111133241133241133221111
		After Filtering	*1324132413241*	*1324132413211*
	3	Before Filtering	1111111113244111133211433411111 1	1111332241111333224111113222411 111
		After Filtering	*1324132143411*	*1324132413241*
#8	**Final Representation Code Taken after Filtering**		**1324132413411**	**1324132413241**

Table 6 Reports Results Of The Two Individuals (9 And 10) Of This Paper.				
9	1	Before Filtering	1111442233111144223111111332411 1322411111	1111111144422222311111144422223 1111113333224411111332244111111 1
		After Filtering	*14231423132413241*	*14231423132413241*
	2	Before Filtering	1111111111444222233311111442222 3311111113322244111113322224111 1111	1111111111144444422222333111111 1444422233311111111133332244111 1144333222411111 1
		After Filtering	*14231423132413241*	*14231423132413241*
	3	Before Filtering	1111111111111444444422222333333 3111111111114444222222333311111 1 1111133333322222441111	1111111111144444222233331111111 1444222233311111111333332222441 1 1111111113332224411111111
		After Filtering	*14231423132413241*	*14231423132413241*
#9	**Final Representation Code Taken after Filtering**		**14231423132413241**	**14231423132413241**
10	1	Before Filtering	1111142222241111142222411113222 2311113222223111 1	1111114422222411111142222222411 1 1332222231111133222223111 1
		After Filtering	*14241424132313231*	*14241424132313231*
	2	Before Filtering	1111111114222222411111144222222 2411111132222222311111133222222 23111111	1111111111144422222222224441111 1 1144222222222441111113332222222 3 3111111332222222231111 1
		After Filtering	*14241424132313231*	*14241424132313231*
	3	Before Filtering	1111111114422222224111111422222 2241111113322222233111111133222 222233111111 1	1111111442222211114222411133222 2 3311113222223111111 1
		After Filtering	*14241424132313231*	*14214241323132311*
#10	**Final Representation Code Taken after Filtering**		**14241424132313231**	**14241424132313231**

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Next, the final target vector of this idea is extracted namely the Final Representation Code Taken after Filtering among the three samples. The idea of selection is based on picking up maximum iterative digit among the three samples. For example, user_1 has trained sample-1, 2, and 3 as: 1 4 2 3 1 4 2 3 1, 1 4 2 3 1 4 2 1 1, and 1 4 2 3 1 4 2 3 1 respectively, and the #user_1 is calculated as #user_1: 1 4 2 3 1 4 2 3 1, which is used to represent the trained feature vector of user_1. The underlined digit in the eighth sequence order in sample 2 differs from the other two samples (samples 1 and 3). Once maximum iterative number is 3, which is available in both samples 1 and 3, therefore, the digit 3 is selected to be put in the final feature vector and so on this idea is applied to whatever user. On the other hand, testing feature vector of #user_1 is 1 4 2 3 1 4 2 3 1 in which theirs directional code have been collected from the following three samples as 1 4 2 3 1 4 2 3 1, 1 4 2 3 1 4 2 3 1 and 1 4 2 3 1 4 2 3 1. Now, False Rejection Rate (FRR) is calculated based on matching the trained and tested directional feature vector. Here, it is assumed to take 3 samples for each training and testing. However, if the sample numbers are increased, then that will highly consolidate the recognition rate for an individual. Therefore, it is noticed during extensive attempts of experiments, three samples are enough for gaining high successful accuracy for differentiation among other users. All users have attained 100% successful rate (FRR=0) except user_8 due to error happened when user_8 originated his/her samples recording, as well as the pointing a finger was not so clear compared with the writs so that this algorithm could not recognize well that sign whether it is upper of lower. Accordingly, it is essential to ask the user to stretch his/her writs when they originate their sample for enrolment or testing. Figure 7 illustrates the ultimate accuracy for this research work that all users have 100% successful accuracy except user_8 which has error rate 15.6 %.

It is worth to mention that the security of the proposed biometric technique dramatically depends on the length of the directional gesture code. In other words, the longer the code is, the more secure the system is. In addition, system administrator can control on the security such as by teaching or offering guide to users so as to inform the user to extend the given gesture for a better security. In terms of the recognition rate or user identification, trained sample numbers are important to build a consolidated reference model to be depended on it later on. In terms of the security matters, a question could be raised by someone that, can an adversary

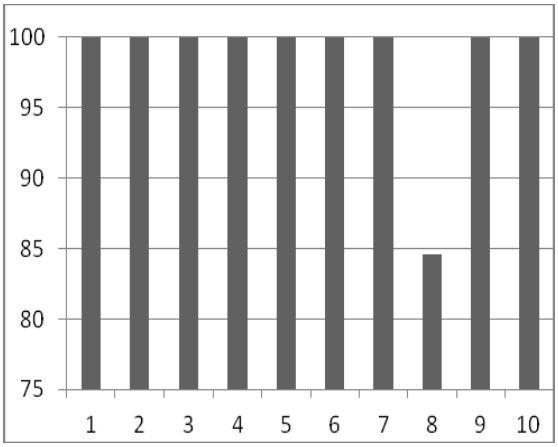

Figure 7. Accuracy For Each Of The 10 Users Tested In The Experiments.

steal the user gesture once he/she is giving the gesture?, the author‘s answer is that, it is bounded to be happened, it is like handwritten signature, it could be mimicked easily. However, in case of commercialization, each individual might be given a special place or detected section for doing the hand gesture so as to prevent any kind of mimicking and stealing the gesture.

Table 7 shows a comparison of the proposed biometric modality of hand-gesture recognition with other existing work in the literature in terms of the accuracy and type of the methodology.

Table 7 Proposed Work Compared With Existing Work In The Literature.

Methodology	No. of Individuals	Avg. Error %	Year / Ref
2D-coordinates are extracted using PCA and DTW as classifier	SIGAIR 10	2.5	2015 / [31]
Proposed work Area of Finger as feature with Expert System classifier	**10**	**1.6**	

6. CONCLUSION

In this paper, new behavioral hand gesture biometric modality has been invented and tested with a fruitful result, which is verifying human being by his/her hand gesture based on hand direction as a sequence of the following codes: 1, 2, 3 or 4, as four directions either with free clockwise or anti-clockwise gesture given. This technique starts by recording gestures of a user in a specific

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time period using camera. Then, the hand is detected in each frame using hand skin color based on YCbCr with motion differencing. Afterward, hand segmentation by converting the frame into binary image, noise removing and largest object search in order to ensure removing all object except the hand object. The final feature vector will be area of the hand object (convex). The classifier used in this work is based on expert system. Finally, it is essentials to add redundant direction filtering operation in order to avoid problem that might be encountered by the individual whether one time gives fast gesture and later on, gives the same gesture but it is slow. The experimental results using 60 video frames distributed among 10 users, who have participated with this experiment, demonstrate that 98.46% accuracy has been observed.

In future work, adding extra direction code such as up-right and up-left, down-right, and down-left as well as to the already existing four directions in this paper namely up, down, left and right, in order to increase the security for the hand gesture code.

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