Automated Cheating Detection based on Video Surveillance in the Examination Classes

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Roa'a M. Al_airaji[1(✉)], Ibtisam A. Aljazaery[2], Haider Th. Salim ALRikabi[3], Abdul Hadi M. Alaidi[3]
[1]Information Technology College, Babylon University, Babylon, Iraq
[2]Engineering College, Babylon University, Babylon, Iraq
[3]Electrical Engineering Department, College of Engineering, Wasit University, Wasit, Iraq
roaaalairaji90@gmail.com

Abstract—A major issue in the field of education is exam malpractice and other forms of academic dishonesty, where efforts made towards the assessment of students are undercut. In order to address this menace, a cheating detection system has been proposed in this study. The system can detect cheating in real-time. The proposed system uses video surveillance to monitor the activities of the student during exams, especially abnormal behavior. The development of the system involved the use of three different techniques, with different functions. The first technique helps in determining the direction of the students' heads when they move from their initial direction, which is the exam script. Some form of cheating involves students peeping at the exam scripts of other people writing the same exam. Whenever the system observes a deviation that exceeds the set threshold, it classifies the behavior as abnormal. The second technique works with the movement of the student's iris. It detects when a student's iris moves in a different direction to copy answers from written documents like mobile phones, books, hands, summary papers. The third technique is used in identifying the contact between a student's hands and face, as well as that between different students for shared abnormal behavior detection between students, such as sharing of incriminating materials. When any of these is detected, an automatic alarm alerts the authority about the abnormal behavior that has been detected, thereby minimizing the error rate that can occur as a result of manual monitoring.

Keywords—surveillance videos, videos analysis, behaviors recognition, anomaly detection, neural networks

1 Introduction

Surveillance is the process through which a behavior, activity, or unusual behavior is monitored with the aim of directing, protecting, managing, or influencing them [1, 2]. In government agencies, the use of surveillance is employed in crime investigation, gathering of intelligence, or safeguarding a procedure, person, or object. Effective video systems designed for surveillance work by detecting suspicious or unusual behavior. Recently, the use of these systems has proven to be efficient in the detection of suspicious or unusual behavior, which in turn enables the prevention of security breaches [3, 4].

The faces of humans as well as their patterns of behavior are crucial to the process of identifying an individual, which mainly relies on visual details. The details of an individual's physical appearance are obtained using the surveillance video which can be played back after it has been recorded or can even be recorded for live viewing as the activity is being recorded. The influence of the modern tendency of 'automation' is felt in every sphere of life, including the area of video analytics [5, 6]. There is a wide variety of domains in which the use of video analytics can be employed, including identification of humans, prediction of human behavior, recognition of abnormal activity, detection of motion, vehicle counting, people counting at crowded places, etc. [7]. Two ways that a person can be identified are through recognition of gait and faces. The recognition of faces varies in terms of automatic recognition through video surveillance. The use of face recognition can be employed in predicting the head orientation of a person, which can, in turn, enable the prediction of a person's behavior. A combination of movement detection and face detection can be effective in producing desired results in several applications like person verification, identification of individuals, and detection of a person's presence or absence at a given location and time [8]. More so, an identification and recognition system for the detection of unusual activity among students writing exams can be developed based on estimation, subtle contact, detection of head motion, recognition of hand gestures.

The field of education has experienced academic dishonesty, especially cheating during exams as a big challenge [9, 10]. Normally, in an offline exam setting, students are monitored manually by human invigilators and surveillance videos globally. However, monitoring an exam hall in this manner can be prone to errors and may not produce the best results. The attention of a human invigilator can be diverted, thereby reducing the focus of the invigilator on all students; this can give room for cheating during an examination [11, 12]. Manual supervision is a very challenging task as it requires sufficient and efficient manpower to carry out the work effectively. However, this is usually not possible to achieve, and this makes it important to have a video surveillance system through which suspicious and abnormal behaviors can be automatically identified and minimized suspicious and abnormal behaviors during exams. More so, with an automated video surveillance system, the possibility of inaccuracy can be minimized to a large extent, while the efficiency of an academic examination system can be increased [13]. In this paper, a real video of students captured while writing an exam in an exam hall is used in analyzing the activities and behaviors of the students. With this, the captured behavior of students can be categorized as abnormal or normal. The approach which is proposed in this paper is capable of recognizing abnormal actions and motions of the iris and head, which in turn prevents students from involving in exam malpractice. Also, the proposed system is capable of detecting position swapping by students or leaving a position. Lastly, with the system, contacts made among students can be detected, thus, preventing the exchange of incriminating materials.

2 Research method

Figure 1 below shows the proposed system, which is made up of different stages, starting with the preprocessing step that is made up of three sub-stages (splitting of input video into frames, elimination of noise and detection of an object in motion, then the introduction of the pre-processed frames into the system. Also, this system makes use of three key methods for the detection of movement, which are, detection of iris movement, detection of head movement, detection of hand movement. Lastly, the behavior detected by the system is classified as either abnormal or normal. As output, the system raises an alarm to notify the authority of the abnormal behavior that has been detected.

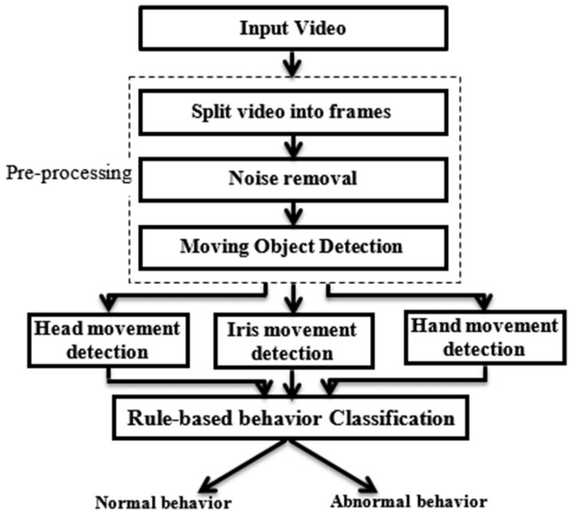

Fig. 1. Student behavior detection system

2.1 Pre-processing

At the beginning of the pre-processing, the input video is split into frames and then the noise is removed through the use of Gaussian filters. After these processes, the next is the detection of moving objects, and this stage is made up of two sub-stages (modeling and background subtraction. The outcome of the detection of objects in motion is foreground frames that are made up of moving objects. There are two Backgrounds. Firstly, the Background model refers to the background image that contains just static objects and the environment in the video. A background model can be derived through two ways, which are Initialization of background model and maintenance of background model. In the first step, the median algorithm is used; the efficiency of this algorithm is hindered when the moving objects remain static for 60% of the period required for training, during which the addition of the moving objects is made to the background image, thereby yielding incorrect intensity values. A more efficient algorithm produces the Highest Redundancy Ratio (HRR) as it can create background images by considering redundant pixels during the training stage, therefore overcoming the aforementioned problem of incorrect intensity values [14]. In the second step, the background is updated constantly due to the addition of certain external factors (such as minor displacement of the camera, little modifications made to the background, changes in lighting) to the background, especially when the motion objects are unfailingly in a static state. These are an integration of the modifications with the present background image. In this regard, there are two adaptations that the system follows; sequential and periodical adaptations. Sequential adaptation involves the use of a mathematical background model, where a low-pass filter is applied to each pixel. The statistical background model also provides the mechanism which allows the system to adapt to minor changes made in the background. On the other hand, the use of periodical adaptation is employed when there is a need to synchronize lighting with other physical changes that may be made to the background such as the removal or addition of objects in the system [15, 16]. Secondly, Background Subtraction: method of adaptive background subtraction refers to the approach that is employed to detect the foreground objects from the n image. To get the foreground image, Equation (1) below can be used. Where In(x) denotes the current value of intensity at pixel x and Bd(x) indicates the current background intensity value at pixel x, then x represents the foreground pixel if the equation (1) below is derived [14, 17].

$$\left| In(x) - Bd(x) \right| > Tn(x) \qquad (1)[8]$$

While the initial set to an experimental value of non-zero value which is denoted as $sT_0(x)$ and the first frame's initial is represented by $Bd_0(x)$, together $T_0s(x)$ and $B_{d0}(x)$ are constantly updated.

2.2 Detection head movement

Subsequent to the pre-processing, the next step involves the detection of head movement. The head detection technique helps in determining the direction of the student's head, especially when it deviates from the answer script to a different direction. This technique is particularly efficient in a situation whereby, students are peeping at other students' answer scripts. If the behavior goes beyond the set threshold, then the system classifies the behavior as abnormal. There are two sub-phases involved in head detection.

Face detection. In this work, the use of Viola-Jones Algorithm is employed in the detection of the face so that high accuracy can be achieved. Also, the features of the face were extracted using Gabor filters, while PCA was used for the reduction of data dimension. Lastly, the classification was done using a backpropagation neural network.

Face recognition with Viola and Jones algorithm. In this study, the detection of the face has been achieved using the Viola-Jones algorithm. The preference for this algorithm is based on the fact that it can run in real-time with a high rate of detection accuracy. As output, the algorithm separates faces from non-faces from the original image. In other words, the algorithm extracts the image of faces from the authentic image. There are three major stages in Viola and Jones's algorithm, which involves the use of three algorithms including, integral image extraction and its features, cascade classifier, and Ada Boost. The Integral Image refers to an algorithm that is cost-effective in generating the total intensity values of a pixel within a given rectangular area of an image. Using this algorithm, the Haar structures that are used in the Viola-Jones detector can be calculated speedily. Equation (1) below is used in calculating integral images. In an integral image, the position of (x, y) is calculated by summing the pixels to the above and left of that location [18].

$$G(x,y)=\sum_{x'\le x,y'\le y} I(x',y') \quad (2)[16]$$

Where I denote the original image, while the integral image is represented by G. One of the most efficient ways of calculating the total of any rectangle region is the use of the integral image as presented in Figure 2. In computing all the pixels in rectangle ABCD, only four values are wanted from the essential image.

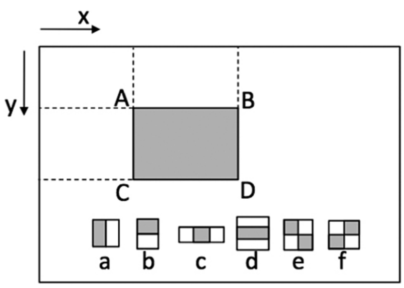

Fig. 2. Fundamental image and Haar features (sixe kinds)

In this paper, two kinds of Haar-like features are extracted for every image sample: the perpendicular feature and the flat feature (kind (a, b) in Figure 2). Here the total of the white pixels is subtracted from the total of black pixels to enable the computation of a Haar-like feature value. In the case whereby the value of the Haar-like feature is beyond the given threshold, then it is pointing to a part of the face like nose, eyes, and cheeks. **AdaBoost** is an algorithm of learning classification that is deployed in both the selection of a few features and training of the classifier [19, 20]. It is used when there is a need to compute a large number of Haar features for each rectangular area. To reduce the redundancy of the features, the use of Ada boost is employed. The algorithm achieves this by determining and eliminating the insignificant features, followed by the conversion of the huge amount of significant features into consolidated one. Ada boost is a multifaceted algorithm that is created using the weighted combination of weak classifiers. Its robustness lies in its ability to choose the best features from the extant features, and as such, it can be regarded as a feature selection algorithm. Ada boost can choose features that are important enough for face characterization [17]. **Cascade classifier** is made up of different steps, containing a strong classifier from AdaBoost. At every phase, the status of an image is determined (whether or not it is face). If during a given phase, the algorithm classifies a sub-window as a face, it is then moved to the subsequent phase in the cascade. If classified as otherwise, then the image is discarded immediately [21, 22].

Features extraction using Gabor filters. This sub-phase involves the extraction of features from the images, which may be images of faces or non-faces. Subsequently, the features vector that has been selected is then moved to the next phase. In this work, the use of Gabor wavelets filters has been employed in the extraction of features. The use of Gabor filters transform has been employed in this study for two purposes, which are to enhance the orientation and resolution properties of the image. It is also an efficient method of measuring local spatial frequency. Gabor filters are one of the most effective ways to separate and represent texture because the manner in which it performs these tasks is similar to that of human visual perception. A 2D Gabor filter represents Gaussian functions that are created through sinusoidal waves. The reason for the use of the 2D Gabor wavelet filters is to acquire features vector which is meant to be used as input in the next stage of the system; this will help in producing the most significant features of the face image [23, 24]. The coefficients of Gabor consist of both real and imaginary parts that are created through the use of a complex function that combines both, or the two could be used independently as presented in the three equations below [25].

The complex part:

$$g(x,y,\lambda,\theta,\Psi,\sigma,\gamma) = exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right) exp\left(i\left(2\pi\frac{x'}{\lambda}+\Psi\right)\right) \qquad (3)[12]$$

The imaginary part:

$$g_I(x,y,\lambda,\theta,\Psi,\sigma,\gamma) = exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right) sin\left(2\pi\frac{x'}{\lambda}+\Psi\right) \qquad (4)[12]$$

The real part:

$$g_R(x,y,\lambda,\theta,\Psi,\sigma,\gamma) = exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right) cos\left(2\pi\frac{x'}{\lambda}+\Psi\right) \qquad (5)[12]$$

Where: $x' = x\cos\theta + y\sin\theta$, $y' = x\sin\theta + y\cos\boldsymbol{\theta}$, γ: Spatial aspect ratio, σ: Sigma, ψ: Phase offset, θ: Orientation angel, λ: Wave length.

3 Reduction of features using PCA

Subsequent to the extraction of features from the image using the Gabor filter, the next step is to reduce the features so that the processes of converging and training will be completed within a reasonable time frame. To achieve timely processing of the features, the features must be reduced as the NN classifier cannot be fed with the large number of features that need to be classified as either face or non-face, because this will consume a lot of time. Thus, the use of PCA is employed in reducing the dimensions of the features which is the input dataset. This involves the removal of redundant or irrelevant details from the data and retaining the relevant ones. This way, the complexity of the process and time required for the detection of the face is reduced, thereby enhancing the optimal performance of the classifier [26].

The PCA works by reducing the high dimensionality of the input data to low dimensions. Thus, it is possible to reduce the dimensions of the input data to N where (N less than M) when the PCA algorithm is used for a particular vector x of M dimension and a correlation matrix R, as shown down [27].

1. Calculate the eigenvalues λ_i and their corresponding eigenvectors $\boldsymbol{Q_i}$ of the correlation matrix $\boldsymbol{R}$:

$$R\boldsymbol{Q_i} = \lambda_i Q_i \tag{6}$$

2. The eigenvalues are reordered in descendant order:

$$\lambda_1 > \lambda_2 > \ldots > \lambda_N > \ldots > \lambda_M$$

3. The eigenvector of the first N highest eigenvalues is selected.
4. The compacted vector $\boldsymbol{C}$ is calculated by:

$$C_i = x^T Q_i \quad \text{for } i = 1, 2, ..., N. \tag{7}$$

4 Arrangement via neural network (NN)

The database which was used in this paper is made up of several faces and non-face images. The Neural Network is trained to classify face/non-face images by using the extracted features of the images, whose dimensions have been reduced. For classification, the use of the backpropagation neural network has been employed, while the face/non-face database has been processed using the Gabor filter. Subsequently, the dimension of the resulting arrays is reduced using the PCA. The BPNN is trained to detect facial/non-facial features using the resulting PCA. The architectural design of the BPNN is characterized by three strata Feed Forward Neural Network, and supervised learning was employed in BPNN training [28]. The function which activates the hidden layer is referred to as the sigmoid function. The following sub-sections provide brief descriptions of the three layers:

The input layer: the input layer is the layer that receives the training patterns which are afterward distributed to other layers regularly. The number of input data points per pattern depends on the number of nodes in this layer. The number of neurons is fixed at (10), depending on the dimension of the input pattern vector.

The hidden layer: this layer is characterized by a specific number of neurons that must be synchronized to the sizes of the input and output layers and other network parameters. The parameters are used for the evaluation of the system's training and testing performances.

The output layer produces the results of the neuron using a threshold function, where (0) denotes non-face, while (0) means face.

Detection of face overlapping. This stage involves checking the direction of the face that has been detected from the image frame. In an event that the space between the positions of the detected faces from one frame to the other is more than a given threshold value, then the behavior will be judged as abnormal. The steps involved in the detection of face overlapping are described as follows:

1. After the first video frame has been subjected to the process of face detection, the number of faces detected as well as the coordinates of each face within the frame are calculated and stored.
2. In the next step, all the relevant head movements within the sequencing frames are detected according to a certain threshold value. The threshold value set in this paper is T=64. The equation below describes this process.

$$((store(xcrdt1) + T < vctr(xcrdt1))||((store(xcrdt2) - T) > vctr(xcrdt\ 2)) \quad (8)$$

Where (*store*) is made up of the number of faces that have been detected as well as the coordinates of each face contained in the first frame. Meanwhile, *vctr* is made up of the coordinates of the face found in the current frame as well as its corresponding details. (*xcrdt1*, *xcrdt2*) – represent the *x* coordinates of sequence frames.

3. When the condition in equation (8) is fulfilled, it implies the presence of a significant head, pointing to the existence of anomaly behavior within the frame.

4.1 Iris movement detection

The path in which the student's iris is moving towards to cheat using a written text is determined through this technique. If the system detects that the iris of the student is looking within the right near peripheral vision and the left near peripheral vision with the heads stable at one position, while the transitory period of the focus of the eyeball is 1, 2, and 3 seconds, then the system classifies the behavior as abnormal. There are four key subsections involved in the process of Iris Movement Detection: detection and tracking of the face, detection of facial features' points, detection and tracking of regions of the eye, as well as detection of regions of the iris. The process of Face detection and tracking has initially been completed at the initial phase described above. The detection of the Facial features points is dependent on the face position that has been detected as well as its area; the active shape model is used in detecting the facial feature points. After the detection of the facial features points, the regions of the left and right eye which are rectangular from the face are automatically estimated. Through the use of a Vector Field of Image Gradient (VFOIG), the center of the iris is detected. This method is regarded as an efficient method because it provides very relevant details about circular objects like the iris. The mechanism through which the VFOID detects the middle of the circular is described in Figure 3 below. The use of VFOIG has been employed in this study given the circular nature of the iris since it works with circular objects. In this method, the orientation of every gradient vector is used in drawing a line across the whole image. Subsequently, the accumulator bin is increased whenever any of such lines pass through it. Where the majority of the lines intersect, the center of the iris is projected as the accumulator bin.

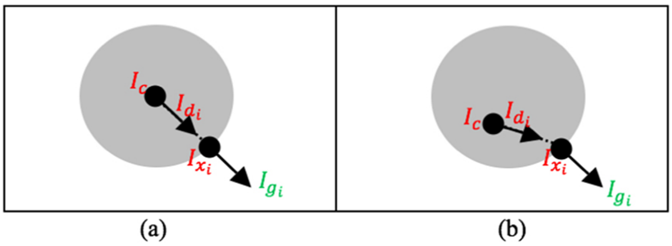

Fig. 3. A summary vision of iris sclera: (a) the gradient vector and movement with the identical alignment; (b) the gradient vector and movement with diverse alignment [29].

The VFOID employed in this work is described as follows: where Igi denotes the gradient vector in location Ixi, and Ic represents the possible iris center. The normalized displacement vector Idi must have identical absolute orientations like the gradient Igi. To determine the iris' optical center I_c^* (which is the darker part of the eye), the dot product of Igi and Idi should be calculated, and the global maximum of the dot product above the eye should be derived as represented in the equation [16] below:

$$I_c^* = argmax I_c \left\{ \frac{1}{N} \sum_{i=1}^{N} \left(\mathrm{Idi}^T * \mathrm{Igi} \right)^2 \right\} \tag{9}$$

Where

$$\mathrm{Idi} = \frac{\mathrm{Ixi} - I_c}{\left| \mathrm{Ixi} - I_c \right|_2} \tag{10}$$

I = 1, ..., N, the displacement vector Idi should be scaled to unit length so that an equal weight can be achieved for all pixel positions in the image.

4.2 Detection of hand movement

This method is specifically considered to enable the identification of the abnormal behavior that is common among the students, such as the exchange of incriminating materials. This algorithm is made up of two functions. The first function involves the construction of squares around the objects which are the hands, and then the algorithm analysis if the boundaries of the box of two examinees are connected. The second function involves checking if two students are in direct contact with each or not. There are four sub-stages which the hand movement detection algorithm is made up: skin detection, face detection, edges detection, and movement detection. The detection of faces has been completed at the first phase described above. As a first step in the process of skin detection, the RGB color space is converted into a YCbCr color space. The next step is the extraction of skin regions based on the frame that corresponds with the YCbCr color space. To find the skin regions, the equations are used:

$$Cb >= 77 \;\&\&\; Cb <= 127 \;\&\&\; Cr >= 133 \;\&\&\; Cr <= 173 \tag{11}$$

If the conditions above are satisfied, the regions of the skin color can e extracted from the image structure. For the human hand to be detected, the result of the detected face must be extracted.

Movement detection involves identifying movement through the subtraction of two successive frames, and then the amount of movement is produced by the resultant image. If the various images are combined with equation (11), the region of dynamic skin color that has some activities is conserved, whereas, the areas of static skin color within the image are eliminated. Apart from the faces objects, the movement that occurs within the frames is represented by the areas of dynamic skin color.

Edges detection this process of detection aims to build squares around the hands that have been detected. In this work, the use of canny edge detection technique has been employed in detecting the edge of the hand. After the edges have been detected, the centroids of the hands are calculated while the squares surrounding the objects are pinched. This edges detection attempts to map out the boundaries of the hands alongside their corresponding faces [30]. Direct contact among two hand objects can be detected through two steps: From the first frame, a given label/flag is used to differentiate and specify two hands belonging to a face. Also, the coordinates of each hand object are stored. Anytime a contact is detected between two hands, the system will need to ascertain the correspondence between the hands and the face. 2) if the system understands that the two hands are for two different persons, then it will raise an alarm. The following algorithm can be used to calculate the detection edges.

```
For every contact hand areas
    If flag (handcrdt1)! = flag (handcrdt2)
        Raise alert
    End
End
```

Flag: the flag which is used in determining which hand belongs to which face is returned.

*handcrdt*1, *handcrdt*2: denotes to the hand coordinates of the detected hand area.

Rule-based performance classification. After the movement of the head and movement of the iris have been determined, the behavior is then classified by the proposed system. This stage involves the recognition of behavior that can be placed under the classify of normal or abnormal. If the system classifies the behavior of the student as abnormal, then more attention should be given to that student.

5 Results and analysis

This sub-section presents the results that were obtained after inputting the videos into the system. When the output video is played, it can be observed that the irises, hands, and faces for all students in the input video are surrounded by a green square which is the frame of the input video. If abnormal behavior is detected by the system, the system puts a red square around the hands, irises, and face of students that are involved in the abnormal behavior that has been detected. The red square serves as an alert to the authority who is viewing the output video from the system. Figure 4 below shows the results. The input video's outcome showing the usual behavior that has been detected is presented in Figure 4a. In this video, the squares are in green color because the detected behavior is normal. On the other hand, Figure 4b indicates the detection of abnormal behavior, whereby, a student has captured copying answers from a mobile phone. Similarly, the video in Figure 4c indicates the detection of abnormal behavior, whereby, a student is captured while taking a peek into another student's answer sheet. The system surrounds the face of the student who is captured taking a peek with a red square so as differentiate him from his neighbor. Figure 4d presents the input video results, showing the exchange of cheat materials between two students. The system surrounds the hands of both students with red square because their activity is recognized as abnormal behavior. However, each student's face is surrounded by a green square since their face remains within the set threshold.

Fig. 4. Results (a) Actual performance (b) cheat the solution from the cell-phone (c) one student glancing at the answer sheet of the other (d) a cheating paper is exchanged Between two classmates; a cheating paper is exchanged.

6 Conclusion

In this article, an automated surveillance system that detects any abnormal behavior exhibited by a student during exams has been presented. The application of this system is critical in detecting and recognizing an abnormal behavior (cheating) during an examination. This system is more efficient than humans because human error can emerge as a result of fatigue or sickness; these factors hamper on the performance of human invigilators. This paper proposes different algorithms for the identification and detection of the movements of the hands, eyes, and heads or students. The system performs the classification of the student's activity as abnormal or normal. More so, the system surrounds the eyes, hands, and faces that have been identified with a green square, but when these body parts go beyond the set threshold, the color of the square changes to red, indicating an abnormal behavior.

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8 Authors

Roa'a M. Al_airaji received the Bachelor degree from Department of Computer, College of Science, University of Babylon, in 2012. Received the Master degree from Department of software, College of Information Technology, University of Babylon, in 2018. Currently work as assistant teacher in College of Science, University of Babylon.

Ibtisam A. Aljazaery is presently Asst. Prof. and on the faculty of Electrical Engineering Department, College of Engineering, University of Babylon. Babylon, Iraq. Email: ibtisamalasady@gmail.com. The number of articles in national databases – 10, The number of articles in international databases – 5.

Haider Th. Salim ALRikabi is presently Asst. Prof. and one of the Faculty College of Engineering, Electrical Engineering Department, Wasit University in Al Kut, Wasit, Iraq. He received his B.Sc. degree in Electrical Engineering in 2006 from the Al Mustansiriyah University in Baghdad, Iraq. His M.Sc. degree in Electrical Engineering focusing on Communications Systems from California State University / Fullerton / USA in 2014. His current research interests include Communications systems with the mobile generation, Control systems, intelligent technologies, smart cities, and the Internet of Things (IoT). Al Kut City-Hay ALRabee, Wasit, Iraq. Email: hdhiyab@uowasit.edu.iq. The number of articles in national databases – 15, The number of articles in international databases – 45.

Abdul Hadi M. Alaidi is a Asst. Prof. in the Engineering College, at the Wasit University, Iraq. His area of research focuses on algorithm and image processing.

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