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IFRS: An Indexed Face Recognition System Based on Face Recognition and RFID Technologies

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Abstract Access control systems are in contact with humans in everyday life, it is used in buildings, smartphones, cars, and IoT. Access control systems became an active research area. The performance of an access control system is specified by its speed and accuracy. Biometric systems are powerful access control systems which use humans' biological or physiological properties to provide access to the restricted data or area. From all of the many biometric system types, the face recognition system is the only type that is delivering the automatic property. Moreover, it is the most acceptable type of biometric systems to the humans. The main challenges in the face recognition system are the degradation of the speed and accuracy when the system database grew bigger. This is because the face recognition system is an identification system that adopts a one to many (1:M) relationship. As a result, there is a need to develop a system with one to one (1:1) relationship, which is a challenging process. Motivated by such challenge, this paper proposes a system called Indexed Face Recognition System (IFRS) which is based on the combination of face recognition technology and Radio Frequency Identification technology. IFRS uses Local Binary Pattern Histogram as a feature vector and Haar-cascade classifier for the face detection. Moreover, the system is enhanced with three pre-processing methods namely: Bilateral filter, Histogram Equalization, and applying Tan and Triggs' algorithm. In addition, IFRS performs an image normalization processes before and after Face Detection phase to enhance images quality, these process are: Color Conversion and Image Cropping and Resizing. Two experiments were done. The first experiment was done on 400 images with 40 subjects (10 images per subject). The second experiment was done on 210 collected images for 21 subjects (10 images per subject) from University students as a real-life case study. The practical results demonstrates that 4×4 image divisions gives better

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results than 8 × 8 image divisions as far as recognition time, database access time, and storage capacity are concerned. The practical results show that IFRS can reach an accuracy of 100% with a very little amount of time delay that is negligible.

Keywords Image pre-processing · RFID · Face recognition · Face identification · LBPH

1 Introduction

In modern life, biometric systems have taken a huge part in recognition systems because of how such systems work. These systems can recognize individuals along from their physiological and/or behavioral properties. As such, the system would depend on an inherent property of the individual instead of depending on "something he know" or "something he have" as in the use of passwords, PINs, smart cards and tokens [1–3]. Passwords and PINs are prone to be forgotten or they might be guessed by someone else, while tokens can also be forgotten at home, lost or stolen. All these causes are security issues that were good reasons to adopt biometric systems as access control systems [4]. The face recognition system is an automatic biometric system and a wide distance system that can recognize individual identity from a distance. Unlike fingerprints and iris systems which provide a more accurate decisions but they would require expensive devices (scanners). Moreover, these systems require an interaction between the system and the person in order to be identified [5, 6]. Some of the people prefer not to physically been in contact with such exposed systems to avoid germs and dirt [6–8].

In general, face recognition system can be categorized into two categories: identification and authentication. Identification is adopting a (1:M) relationship, it is meant to identify a given person among many saved templates and returns his identity. While authentication is adopting a (1:1) relationship, meaning that the system would check a given identity with a saved template and state whether it is accepted or rejected [6].

In our previous work [9, 10], we studied the accuracy enhancement in face identification system by adopting a pre-processing stage that uses one of three methods (or any combination of the three methods) namely: Bilateral Filter [11], Histogram Equalization [12] and the use of Tan and Triggs Algorithm [13]. Our previous work shows that any increasing in database size means increasing in total number of persons in the database file. This would lead to an increasing in the chance of getting a minimum distance from more database file entries and hence a wrong decision may occur. The same cause would lead to the increasing in the number of comparisons between the input image and the database file entries and hence increases the response time. As such, identification system has some drawbacks and would not be a perfect system for large organizations that have many employees because its accuracy is decreasing linearly with the increasing of database file size (number of persons in database). In addition, response time is increasing also with increasing database file size. Figure 1 illustrates the performance of the identification system that has been calculated in the previous work.

Fixing and building from our earlier work, this paper proposes a system called Indexed Face Recognition System (IFRS) which is based on the combination of Face Recognition technology and Radio Frequency Identification (RFID) technology. IFRS is developed in order to produce an authentication face recognition system that adopts a (1:1) relationship.

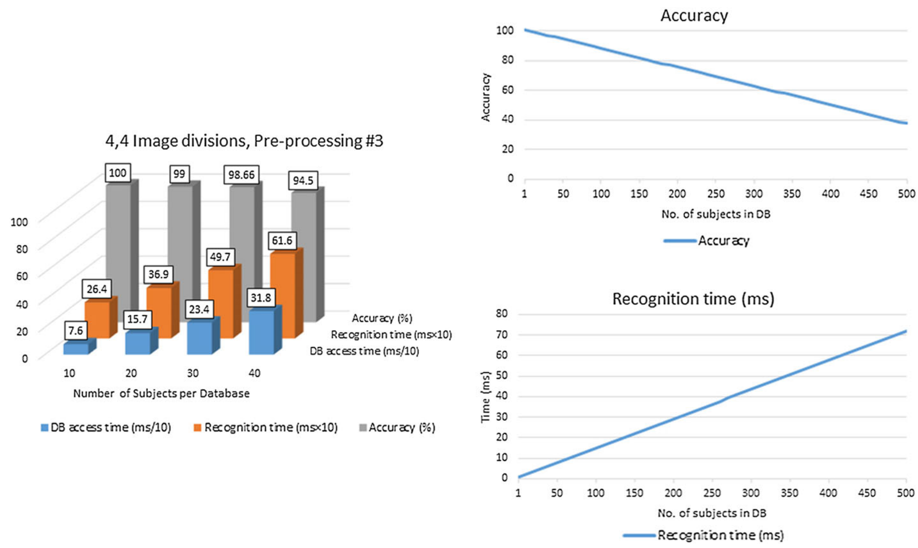

Fig. 1 Performance degradation in identification system in terms of accuracy and recognition time when the number of subjects is increased [9]

2 Design and Implementation

IFRS works in different light conditions by the help of using the pre-processing methods which are meant to improve image contrast and remove the sharpness. IFRS uses Haar-cascade classifier which is an object detector introduced by Viola and Jones [14] that works perfectly in detecting faces in an image. As a feature extraction method, IFRS adopts a Local Binary Pattern (LBP) method which was introduced by Ojala [15] to describe a pattern and calculates the histograms for all possible patterns. Then concatenate all these histograms to form one big histogram called Local Binary Pattern Histogram (LBPH), the last is used as a feature vector that can describe an entire image. Last step is the classification stage that produces the result, either accepted or rejected. This is done by loading database file indexed by RFID tag ID which is previously saved in training process, and then compare the extracted features from input image represented by LBPH with the database file which is also an LBPH. IFRS uses nearest neighbor classification and Chi square (χ^2) statistic to measure the distance between two histograms. If the distance is below a previously calculated threshold, the input image is classified (authenticated) as the RFID tag holder else the input image will be rejected. IFRS flowchart is shown in Fig. 2.

It is necessary to mention that any computerized system is subject to fall into an error. As so, face recognition system output would be one of the following four results: [14, 16]

1. *True Positive* A known entity has been classified as known which is a correct decision.
2. *True Negative* An unknown entity has been classified as unknown which is a correct decision.
3. *False Positive* An unknown entity has been classified as known which is a wrong decision.
4. *False Negative* A known entity has been classified as unknown which is a wrong decision.

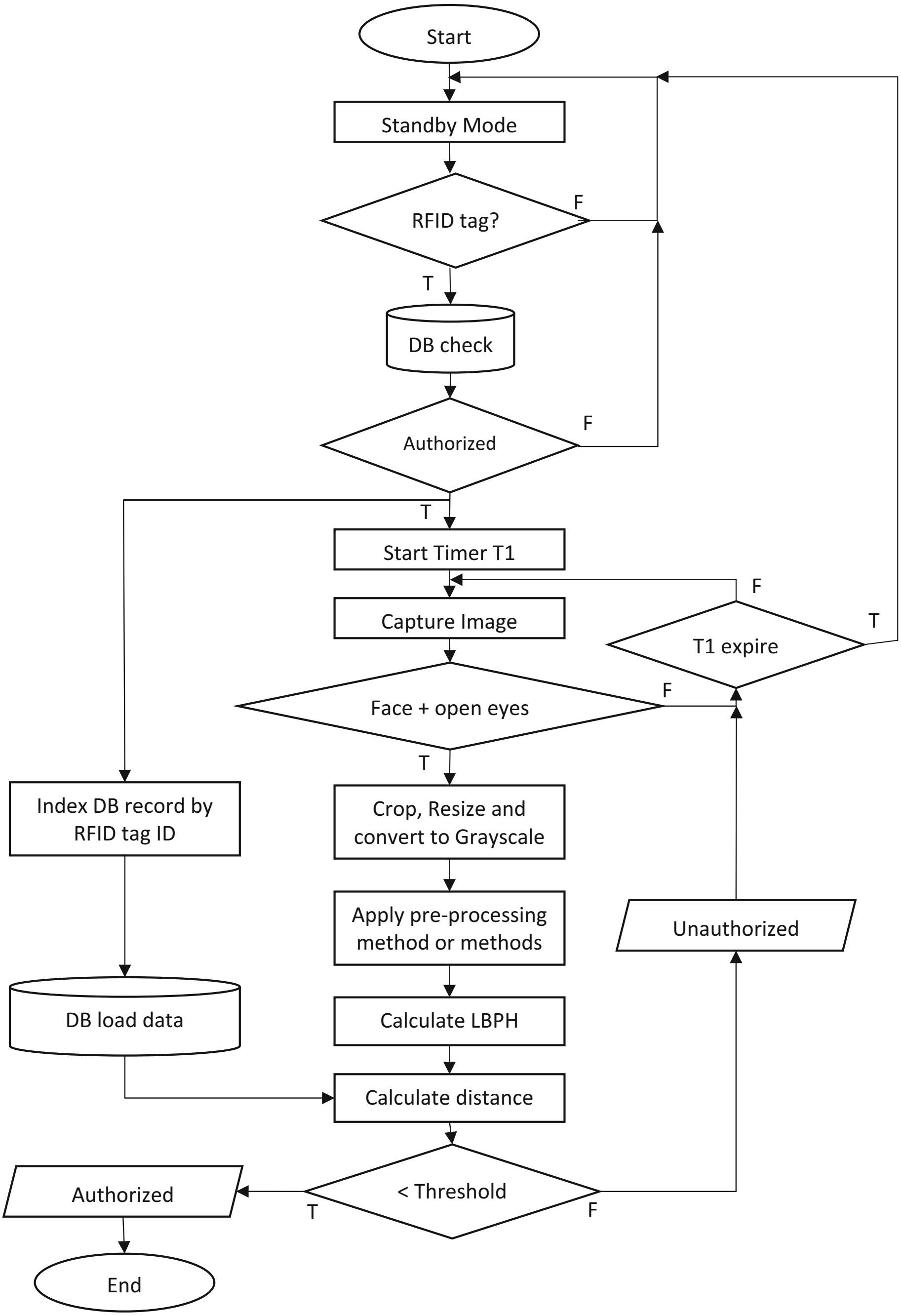

Fig. 2 IFRS flowchart

Table 1 Definition formulas for system outputs

Name	Formula
True Positive rate	$\frac{No.\ of\ known\ subjects\ that\ were\ classified\ as\ known}{True\ Positive\ rate + Flase\ Negative\ rate}$
True Negative rate	$\frac{No.\ of\ unknown\ subjects\ that\ were\ classified\ as\ unknown}{True\ Negative\ rate + False\ Positive\ rate}$
False Positive rate	$\frac{No.\ of\ unknown\ subjects\ that\ were\ classified\ as\ known}{False\ Positive\ rate + True\ Negative\ rate}$
False Negative rate	$\frac{No.\ of\ known\ subjects\ that\ were\ classified\ as\ unknown}{False\ Negative\ rate + True\ Positive\ rate}$
Overall accuracy	$\frac{\text{True Positive rate} + \text{True Negative rate}}{All\ input\ images}$

Output rate and accuracy can be calculated as shown in Table 1.

Moreover, there are some relations between the previous four rates and they are given in the Eqs. 1 and 2:

$$1 = \boldsymbol{FN} + \boldsymbol{TP} \tag{1}$$

$$1 = \boldsymbol{TN} + \boldsymbol{FP} \tag{2}$$

IFRS was hosted on a multithreading system because it uses one thread for RFID reader and another thread is used by the camera. IFRS has been written in C++ programming language and build using Microsoft Visual Studio 2010 with the use of OpenCV library, running on Windows 10 on a machine with specifications listed in Table 2.

3 Experiments, Results and Discussion

In order to evaluate the implementation of IFRS, two experiments will be done. The first one is to apply standard database images to IFRS, while the second one is to use real life images that were collected from a USB web camera, these images were not exposed to an ideal environment and having different light conditions and poses.

Both of these experiments was repeated two times, first time with dividing every image to 4 × 4 regions in order to get a histogram for each region then concatenate all these histograms in one big histogram. While in the second time, IFRS would divide every image to 8 × 8 regions. Within each of those two trials, a different pre-processing method was applied to database images. Hence, each experiment had been made 8 times, one without applying any pre-processing, and the other 7 times with 7 different pre-processing methods as tabulated in Table 3, pre-processing effects are shown in Fig. 3.

Table 2 Host machine specifications

Item name	Type, model and properties
Processor	Intel(R) Core(TM) i7-2630QM CPU @ 2.00 GHz (8 CPUs), ~ 2.0 GHz
Memory	8192 MB RAM
Operating system	Windows 10 Pro 64-bit (10.0, Build 10240) (10240.th1.160104-1507)
Graphics card	NVIDIA GeForce GT 525M
Graphics card memory	4045 MB (Dedicated 973 MB, Shared 3071 MB)

Table 3 Pre-processing methods and corresponding numbers

Pre-processing no.	Pre-processing type
0	Original input image (no filter is applied)
1	Bilateral filter
2	Histogram equalization
3	Bilateral filter + histogram equalization
4	Tan and Triggs algorithm
5	Bilateral filter + Tan and Triggs algorithm
6	Histogram equalization + Tan and Triggs algorithm
7	Bilateral filter + Histogram equalization + Tan and Triggs algorithm

Fig. 3 Input image with all effects of all pre-processing methods

The first experiment has been done on AT&T-ORL dataset [17] which consists of 40 subjects, each has 10 images, each image is a 92 $\times$ 112 pixels. The AT&T-ORL dataset has been chosen because this dataset has images that have a different variation in pose and illumination, with and without wearing glasses, so it would be perfect dataset to give different situations for each subject. The AT&T-ORL dataset is divided in a way that each subject among the 40 has 5 images as training-set and the other 5 images as testing-set. Hence, there will be 200 images for training and another 200 images for testing.

Since it is a simulation and the system forces input test images to be compared with the data from the training images (by the use of RFID to apply a 1:1 relationship) that belong to the same person, the system will give a positive response all the time (i.e. always gives the "authorized" decision as a response). After integrating RFID system with the face recognition system, a threshold was needed. A threshold is a value of recognition distance which that, the input image would be classified as the claimed person (class) if its distance is below the threshold value, and otherwise, it would be classified as unknown. The threshold is needed because the input image is compared with only a single database record (which is indexed by the RFID tag) that contains the extracted features from the claimed RFID tag holder, the result is the distance between those two entries. As so, this distance should be considered to certain limits because the system will always give a distance whether it has a large or small value. It is necessary to mention that IFRS without using threshold will never give a true negative or a false negative (i.e. it will not give a negative response).

It is a perfect system to have a 100% positive response. But unfortunately, without calibrating threshold values, the system can have a 100% FP rate, too. Considering a scenario when the system encountered a test image from another subject that training images were taken from. This happens because the system compares between the input test

Table 4 TP rates of all pre-processing methods with different shift values in threshold for 4 × 4 image divisions applied to standard DB images

Shift in threshold	TP % for 4 × 4 image divisions applied to standard DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	6.19	7.73	6.31	7.24	4.79	5.35	4.83	5.34
0	65.50	65.00	64.50	66.00	60.00	58.00	56.00	57.50
+ 2	85.00	75.50	86.50	80.00	97.50	94.50	96.50	94.00
+ 4	97.50	84.50	97.00	88.00	100.00	99.00	100.00	100.00
+ 6	99.00	91.50	99.50	94.00	100.00	99.50	100.00	100.00
+ 8	100.00	95.00	100.00	98.00	100.00	99.50	100.00	100.00
+ 10	100.00	97.50	100.00	99.50	100.00	99.50	100.00	100.00

Table 5 FN rates of all pre-processing methods with different shift values in threshold for 4 × 4 image divisions applied to standard DB images

Shift in threshold	FN % for 4 × 4 image divisions applied to standard DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	6.19	7.73	6.31	7.24	4.79	5.35	4.83	5.34
0	34.50	35.00	35.50	34.00	40.00	42.00	44.00	42.50
+ 2	15.00	24.50	13.50	20.00	2.50	5.50	3.50	6.00
+ 4	2.50	15.50	3.00	12.00	0.00	1.00	0.00	0.00
+ 6	1.00	8.50	0.50	6.00	0.00	0.50	0.00	0.00
+ 8	0.00	5.00	0.00	2.00	0.00	0.50	0.00	0.00
+ 10	0.00	2.50	0.00	0.50	0.00	0.50	0.00	0.00

Table 6 FP rates for the best 4 pre-processing methods that give best TP rates for 4 × 4 image divisions applied to standard DB images, FP rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	TP (%)	FP % for 4 × 4 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	65.50	0.00	54.50	0.00	0.00	13.63
	+ 2	85.00	0.00	82.00	30.00	3.00	28.75
	+ 4	97.50	8.00	94.50	65.00	52.00	54.88
	+ 6	99.00	28.00	98.00	89.50	91.50	76.75
	+ 8	100.00	54.50	100.00	98.50	98.00	87.75
	+ 10	100.00	74.50	100.00	99.00	100.00	93.38
Tan–Triggs	0	60.00	1.50	46.00	0.00	0.00	11.88
	+ 2	97.50	76.50	96.00	63.50	0.00	59.00
	+ 4	100.00	99.00	100.00	97.50	0.00	74.13
	+ 6	100.00	100.00	100.00	100.00	0.00	75.00
	+ 8	100.00	100.00	100.00	100.00	0.50	75.13
	+ 10	100.00	100.00	100.00	100.00	2.50	75.63
Tan–Triggs + smooth	0	58.00	3.00	40.50	0.00	0.00	10.88
	+ 2	94.50	62.00	89.00	0.00	0.00	37.75
	+ 4	99.00	94.50	99.50	0.00	0.00	48.50
	+ 6	99.50	98.50	100.00	0.00	0.00	49.63
	+ 8	99.50	98.50	100.00	0.00	1.00	49.88
	+ 10	99.50	99.00	100.00	0.00	3.00	50.50
Tan–Triggs + total histogram	0	56.00	0.00	0.00	0.00	0.00	0.00
	+ 2	96.50	73.50	0.00	0.00	0.00	18.38
	+ 4	100.00	99.00	0.00	0.00	0.00	24.75
	+ 6	100.00	100.00	0.00	0.00	0.00	25.00
	+ 8	100.00	100.00	0.50	0.00	0.00	25.13
	+ 10	100.00	100.00	2.50	1.00	2.00	26.38
Tan–Triggs + total histogram + smooth	0	57.50	0.00	0.00	0.00	0.00	0.00
	+ 2	94.00	0.00	0.00	0.00	0.00	0.00
	+ 4	100.00	0.00	0.00	0.00	0.00	0.00
	+ 6	100.00	0.00	0.00	0.00	0.00	0.00
	+ 8	100.00	0.00	1.50	0.00	0.50	0.50
	+ 10	100.00	1.00	2.50	0.00	4.50	2.00

image and the saved training images and produces a distance value. As a result, the distance value should be less than the threshold value to be classified as positive response, otherwise it will belong to an unknown class (negative response). However; if the threshold was not set, then any distance value (whether a large or a small value) will be accepted as a positive classification which may leads to the occurrence of the FP.

Table 7 TN rates for the best 4 pre-processing methods that give best TP rates for 4 × 4 image divisions applied to standard DB images, TN rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	FN (%)	TN % for 4 × 4 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	34.50	100.00	45.50	100.00	100.00	86.38
	+ 2	15.00	100.00	18.00	70.00	97.00	71.25
	+ 4	2.50	92.00	5.50	35.00	48.00	45.13
	+ 6	1.00	72.00	2.00	10.50	8.50	23.25
	+ 8	0.00	45.50	0.00	1.50	2.00	12.25
	+ 10	0.00	25.50	0.00	1.00	0.00	6.63
Tan–Triggs	0	40.00	98.50	54.00	100.00	100.00	88.13
	+ 2	2.50	23.50	4.00	36.50	100.00	41.00
	+ 4	0.00	1.00	0.00	2.50	100.00	25.88
	+ 6	0.00	0.00	0.00	0.00	100.00	25.00
	+ 8	0.00	0.00	0.00	0.00	99.50	24.88
	+ 10	0.00	0.00	0.00	0.00	97.50	24.38
Tan–Triggs + smooth	0	42.00	97.00	59.50	100.00	100.00	89.13
	+ 2	5.50	38.00	11.00	100.00	100.00	62.25
	+ 4	1.00	5.50	0.50	100.00	100.00	51.50
	+ 6	0.50	1.50	0.00	100.00	100.00	50.38
	+ 8	0.50	1.50	0.00	100.00	99.00	50.13
	+ 10	0.50	1.00	0.00	100.00	97.00	49.50
Tan–Triggs + total histogram	0	44.00	100.00	100.00	100.00	100.00	100.00
	+ 2	3.50	26.50	100.00	100.00	100.00	81.63
	+ 4	0.00	1.00	100.00	100.00	100.00	75.25
	+ 6	0.00	0.00	100.00	100.00	100.00	75.00
	+ 8	0.00	0.00	99.50	100.00	100.00	74.88
	+ 10	0.00	0.00	97.50	99.00	98.00	73.63
Tan–Triggs + total histogram + smooth	0	42.50	100.00	100.00	100.00	100.00	100.00
	+ 2	6.00	100.00	100.00	100.00	100.00	100.00
	+ 4	0.00	100.00	100.00	100.00	100.00	100.00
	+ 6	0.00	100.00	100.00	100.00	100.00	100.00
	+ 8	0.00	100.00	98.50	100.00	99.50	99.50
	+ 10	0.00	99.00	97.50	100.00	95.50	98.00

In order to find the threshold value for each type whether or not adopting pre-processing methods (Table 3), each of these 8 trails must be done with test images from the same class as training images were. Hence, 200 test images (5 test images per subject × 40 subjects) will generate 200 distance values. A threshold was found by taking the average of these 200 distance values per pre-processing method. So, 8 thresholds were found, one threshold

Table 8 Accuracies for 4 × 4 image divisions applied to standard DB images

Shift in threshold	Accuracies for 4 × 4 image divisions				
	Original (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
0	75.94	74.06	73.56	78.00	78.75
+ 2	78.13	69.25	78.38	89.06	97.00
+ 4	71.31	62.94	75.25	87.63	100.00
+ 6	61.13	62.50	74.94	87.50	100.00
+ 8	56.13	62.44	74.81	87.44	99.75
+ 10	53.31	62.19	74.50	86.81	99.00

for each pre-processing method (1 without any pre-processing and other 7 for each of pre-processing method). After finding thresholds of all 8 trails, accuracies must be calculated. In order to find a trail accuracy, the same 200 distance values (which the threshold was calculated from them) must be now compared with the threshold. If a given distance value is lower than the threshold, the image would be classified as a known subject (the subject that the person claimed to be by RFID tag which is a positive response) else the input image would be classified as unknown (not the same subject whom RFID tag belongs to and it is considered as negative response).

The "average" metric used was not so good and it would not give a perfect system because it depends on the average value, and ideally, half of distance values are above the average and it would ideally give an accuracy of 50%. To solve such problem, controlled-shifts in the threshold was used with different values in order to increase the threshold in a controlled way until best TP rate with minimum FP rate were achieved. TP rates were calculated and the results are shown in Table 4 for AT&T-ORL database images with setting the image divisions' parameter to 4 × 4 divisions. Furthermore, the table shows TP rates for 2, 4, 6, 8 and 10 shift increments in threshold value. It is clear that TP rates are increasing whenever the threshold increased. However, FP rate will increase too as a result of incrementing threshold value as stated before, allowing for large distance values to be classified as authorized (positive response). FN rate was calculated as shown in Table 5 using Eq. (1).

In order to calculate the FP rate, test images of subjects would be applied to the system when trained with different subject's training images (i.e. giving the RFID tags to different subjects). If the classification distance is below the threshold, then it would be considered as a FP, else it would be classified as unknown (TN) which is a correct classification. FP rates were calculated in a way that random shifts in database file occurs. It means that if a shift by one is applied, subject No.1 test images would be compared with subject No. 2 database record, and subject No. 2 test images with subject No. 3 database record and so on and so forth until subject No. 40 is compared with the subject No. 1 database record. The same is applied with different database shifts: 1, 2, 3 and 4. In each case a false positive rate was calculated for each of the 8 methods used in the experiment; however, Table 6 shows FP rates for only four pre-processing methods that had the best TP rates in Table 4 along with the original image (without applying any pre-processing method) namely: Tan–Triggs method, the combination of Tan–Triggs + Smooth methods, the combination of Total histogram + Tan–Triggs methods and finally the combination of Total

Table 9 TP rates of all pre-processing methods with different shift values in threshold for 8 × 8 image divisions applied to standard DB images

Shift in threshold	TP % for 8 × 8 image divisions using standard DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	44.40	59.07	44.03	54.08	41.62	46.48	41.73	46.25
0	64.00	62.50	63.50	62.50	58.00	54.50	59.00	56.00
+ 5	74.00	69.50	77.50	73.00	78.00	74.00	80.00	74.50
+ 10	80.00	74.00	85.50	76.50	90.00	86.50	88.50	85.00
+ 15	89.50	79.00	91.00	82.00	94.50	92.50	96.00	91.50
+ 20	93.50	82.50	93.00	85.50	99.00	97.00	98.50	98.00
+ 25	96.50	86.00	94.00	88.50	100.00	99.00	100.00	99.50

Table 10 FN rates of all pre-processing methods with different shift values in threshold for 8 × 8 image divisions applied to standard DB images

Shift in threshold	FN % for 8 × 8 image divisions using standard DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	44.40	59.07	44.03	54.08	41.62	46.48	41.73	46.25
0	36.00	37.50	36.50	37.50	42.00	45.50	41.00	44.00
+ 5	26.00	30.50	22.50	27.00	22.00	26.00	20.00	25.50
+ 10	20.00	26.00	14.50	23.50	10.00	13.50	11.50	15.00
+ 15	10.50	21.00	9.00	18.00	5.50	7.50	4.00	8.50
+ 20	6.50	17.50	7.00	14.50	1.00	3.00	1.50	2.00
+ 25	3.50	14.00	6.00	11.50	0.00	1.00	0.00	0.50

Table 11 FP rates for the best 4 pre-processing methods that give best TP rates for 8 × 8 image divisions applied to standard DB images, FP rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	TP (%)	FP % for 8 × 8 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	64.00	1.50	58.00	13.00	0.00	18.13
	+ 5	74.00	7.50	70.50	33.00	0.50	27.88
	+ 10	80.00	23.00	80.00	57.50	1.50	40.50
	+ 15	89.50	46.50	88.00	73.50	10.00	54.50
	+ 20	93.50	71.00	92.00	82.00	23.00	67.00
	+ 25	96.50	82.00	93.00	90.00	38.50	75.88
Tan–Triggs	0	58.00	32.00	51.50	18.00	0.00	25.38
	+ 5	78.00	62.50	72.50	54.50	0.00	47.38
	+ 10	90.00	82.50	87.50	79.00	0.00	62.25
	+ 15	94.50	92.00	95.50	88.00	0.00	68.88
	+ 20	99.00	96.50	98.00	96.00	0.00	72.63
	+ 25	100.00	100.00	100.00	99.50	8.00	76.88
Tan–Triggs + smooth	0	54.50	13.50	43.00	0.00	0.00	14.13
	+ 5	74.00	36.50	68.00	0.00	0.00	26.13
	+ 10	86.50	59.00	81.50	0.00	0.00	35.13
	+ 15	92.50	79.00	90.00	0.00	0.00	42.25
	+ 20	97.00	91.00	95.50	0.00	2.50	47.25
	+ 25	99.00	95.50	99.00	5.00	18.00	54.38
Tan–Triggs + total histogram	0	59.00	28.50	0.00	0.00	0.00	7.13
	+ 5	80.00	61.50	0.00	0.00	0.00	15.38
	+ 10	88.50	84.00	0.00	0.00	0.00	21.00
	+ 15	96.00	90.00	0.50	0.00	0.00	22.63
	+ 20	98.50	97.00	9.00	0.50	1.00	26.88
	+ 25	100.00	99.50	0.00	14.00	12.00	31.38
Tan–Triggs + total histogram + smooth	0	56.00	0.00	0.00	0.00	0.00	0.00
	+ 5	74.50	0.00	0.00	0.00	0.00	0.00
	+ 10	85.00	0.00	0.00	0.00	0.00	0.00
	+ 15	91.50	0.00	0.00	0.00	0.00	0.00
	+ 20	98.00	0.00	1.00	0.50	0.00	0.38
	+ 25	99.50	2.50	14.50	3.00	7.50	6.88

histogram + Tan–Triggs + Smooth methods. Like the FN rates, TN rates was calculated as shown in Table 7 by solving Eq. (2).

The accuracy which can be calculated from Tables 4 and 7 for 4 × 4 image divisions. The accuracies of 4 × 4 image divisions is listed in Table 8. It is necessary to mention that the average of FP rates for different database shifts was considered in accuracies'

Table 12 TN rates for the best 4 pre-processing methods that give best TP rates for 8 × 8 image divisions applied to standard DB images, TN rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	FN (%)	TN % for 8 × 8 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	36.00	98.50	42.00	87.00	100.00	81.88
	+ 5	26.00	92.50	29.50	67.00	99.50	72.13
	+ 10	20.00	77.00	20.00	42.50	98.50	59.50
	+ 15	10.50	53.50	12.00	26.50	90.00	45.50
	+ 20	6.50	29.00	8.00	18.00	77.00	33.00
	+ 25	3.50	18.00	7.00	10.00	61.50	24.13
Tan–Triggs	0	42.00	68.00	48.50	82.00	100.00	74.63
	+ 5	22.00	37.50	27.50	45.50	100.00	52.63
	+ 10	10.00	17.50	12.50	21.00	100.00	37.75
	+ 15	5.50	8.00	4.50	12.00	100.00	31.13
	+ 20	1.00	3.50	2.00	4.00	100.00	27.38
	+ 25	0.00	0.00	0.00	0.50	92.00	23.13
Tan–Triggs + smooth	0	45.50	86.50	57.00	100.00	100.00	85.88
	+ 5	26.00	63.50	32.00	100.00	100.00	73.88
	+ 10	13.50	41.00	18.50	100.00	100.00	64.88
	+ 15	7.50	21.00	10.00	100.00	100.00	57.75
	+ 20	3.00	9.00	4.50	100.00	97.50	52.75
	+ 25	1.00	4.50	1.00	95.00	82.00	45.63
Tan–Triggs + total histogram	0	41.00	71.50	100.00	100.00	100.00	92.88
	+ 5	20.00	38.50	100.00	100.00	100.00	84.63
	+ 10	11.50	16.00	100.00	100.00	100.00	79.00
	+ 15	4.00	10.00	99.50	100.00	100.00	77.38
	+ 20	1.50	3.00	91.00	99.50	99.00	73.13
	+ 25	0.00	0.50	100.00	86.00	88.00	68.63
Tan–Triggs + total histogram + smooth	0	44.00	100.00	100.00	100.00	100.00	100.00
	+ 5	25.50	100.00	100.00	100.00	100.00	100.00
	+ 10	15.00	100.00	100.00	100.00	100.00	100.00
	+ 15	8.50	100.00	100.00	100.00	100.00	100.00
	+ 20	2.00	100.00	99.00	99.50	100.00	99.63
	+ 25	0.50	97.50	85.50	97.00	92.50	93.13

calculations. Similarly, all rates (TP, FN, FP and TN) along with accuracies were calculated again for 8 × 8 image divisions and the results are shown in Tables 9, 10, 11, 12 and 13 respectively.

The second experiment is to expose IFRS to a real time environment. The input to the system would not be in the ideal situations such as standard images from AT&T-ORL

Table 13 Accuracies for 8 × 8 image divisions applied to standard DB images

Shift in threshold	Accuracies for 8 × 8 image divisions				
	Original (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
0	72.94	66.31	70.19	75.94	78.00
+ 5	73.06	65.31	73.94	82.31	87.25
+ 10	69.75	63.88	75.69	83.75	92.50
+ 15	67.50	62.81	75.13	86.69	95.75
+ 20	63.25	63.19	74.88	85.81	98.81
+ 25	60.31	61.56	72.31	84.31	96.31

database images. This experiment is same as last the first experiment but with images that were collected from the department of Computer Engineering at the University of Baghdad. The face images were collected in grayscale mode and with a resolution of 125 × 125 pixels using a USB webcam for 21 subjects containing male and female, some were having glasses and other were not. Some of the females were wearing Hijab. Hence, images set now has much variety and real time conditions. The case study will be discussed in the next section to come.

4 Case Study: Lecture Attendance System Using IFRS

Lecture attendance is used from a long time, and it will be used in the future. It is a system that shows who is attending, when did the student attend and what class did he missed. In addition, it helps to evaluate the students. There are many types of lecture attendance systems like the simple and conventional system of calling students' names to know who is attending. This type is time-consuming and also somewhat expensive (pens and papers) if it considered for several years. Another type is the use of technology, like the use of fingerprints system. Unfortunately, fingerprints system needs an expensive equipment and such system needs a direct contact between students and the system, hence it is not an automatic system and would cause a time delay. The use of RFID system is automatic and fast, but it allows for impersonation because the token may be lost, given to somebody else or even forgotten at home. As such, a development of a lecture attendance system must take care of the following challenges:

1. *Time* The developed system should not take much time that is sensible to the human being and must be faster than the conventional pen and paper system.
2. *Accuracy* The developed system should give a very high accuracy and would not allow for impersonation.
3. *Automatic* The developed system should be an automatic system that it does not need the student to be in direct contact with the system.
4. *Recording* The developed system should have a database that records every attendance to each known subject with the time and date of his attendee.

IFRS is developed to overcome these challenges.

Table 14 TP rates of all pre-processing methods with different shift values in threshold for 4 × 4 image divisions applied to collected DB images

Shift in threshold	TP % for 4 × 4 image divisions using collected DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	4.71	5.18	4.90	5.20	3.53	3.81	3.53	4.02
0	58.10	60	60.95	60.95	62.86	60.95	55.24	58.10
+ 2	93.33	86.67	93.33	88.57	99.05	100	100	100
+ 4	99.05	94.29	96.19	93.33	99.05	100	100	100
+ 6	99.05	98.10	98.10	96.19	100	100	100	100
+ 8	100	100	99.05	99.05	100	100	100	100
+ 10	100	100	99.05	99.05	100	100	100	100

Table 15 FN rates of all pre-processing methods with different shift values in threshold for 4 × 4 image divisions applied to collected DB images

Shift in threshold	FN % for 4 × 4 image divisions using collected DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	4.71	5.18	4.90	5.20	3.53	3.81	3.53	4.02
0	41.90	40.00	39.05	39.05	37.14	39.05	44.76	41.90
+ 2	6.67	13.33	6.67	11.43	0.95	0.00	0.00	0.00
+ 4	0.95	5.71	3.81	6.67	0.95	0.00	0.00	0.00
+ 6	0.95	1.90	1.90	3.81	0.00	0.00	0.00	0.00
+ 8	0.00	0.00	0.95	0.95	0.00	0.00	0.00	0.00
+ 10	0.00	0.00	0.95	0.95	0.00	0.00	0.00	0.00

Table 16 FP rates for the best 4 pre-processing methods that give best TP rates for 4 × 4 image divisions applied to collected DB images, FP rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	TP (%)	FP % for 4 × 4 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	58.10	0.00	2.86	0.00	0.00	0.71
	+ 2	93.33	0.00	56.19	0.00	0.00	14.05
	+ 4	99.05	7.62	90.48	20.95	0.00	29.76
	+ 6	99.05	46.67	90.48	69.52	27.62	58.57
	+ 8	100.00	85.71	91.43	88.57	67.62	83.33
	+ 10	100.00	96.19	93.33	90.48	80.00	90.00
Tan–Triggs	0	62.86	0.00	15.24	0.00	0.00	3.81
	+ 2	99.05	62.86	99.05	20.00	0.00	45.48
	+ 4	99.05	99.05	100.00	95.24	0.00	73.57
	+ 6	100.00	100.00	100.00	99.05	0.00	74.76
	+ 8	100.00	100.00	100.00	100.00	0.00	75.00
	+ 10	100.00	100.00	100.00	100.00	19.05	79.76
Tan–Triggs + smooth	0	60.95	0.00	4.76	0.00	0.00	1.19
	+ 2	100.00	75.24	89.52	0.00	0.00	41.19
	+ 4	100.00	100.00	99.05	0.00	0.00	49.76
	+ 6	100.00	100.00	99.05	0.00	0.00	49.76
	+ 8	100.00	100.00	100.00	9.52	0.00	52.38
	+ 10	100.00	100.00	100.00	30.48	0.00	57.62
Tan–Triggs + total histogram	0	55.24	0.00	0.00	0.00	0.00	0.00
	+ 2	100.00	65.71	0.00	0.00	0.00	16.43
	+ 4	100.00	99.05	0.00	0.00	0.00	24.76
	+ 6	100.00	100.00	0.95	0.00	0.95	25.48
	+ 8	100.00	100.00	19.05	0.00	20.00	34.76
	+ 10	100.00	100.00	0.00	0.00	54.29	38.57
Tan–Triggs + total histogram + smooth	0	58.10	0.00	0.00	0.00	0.00	0.00
	+ 2	100.00	0.00	0.00	0.00	0.00	0.00
	+ 4	100.00	0.00	0.00	0.00	0.00	0.00
	+ 6	100.00	0.00	0.00	0.00	0.00	0.00
	+ 8	100.00	4.76	0.00	3.81	0.00	2.14
	+ 10	100.00	22.86	0.00	25.71	0.00	12.14

4.1 IFRS Operation as Lecture Attendance System

When a student enters the class, he will have to swipe his card (RFID Tag) near RFID reader and made his head towards the camera with open eyes. When RFID Tag is within the read range of RFID reader, the system will check for Tag's authority. If it is authorized,

Table 17 TN rates for the best 4 pre-processing methods that give best TP rates for 4 × 4 image divisions applied to collected DB images, TN rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	FN (%)	TN % for 4 × 4 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	41.90	100.00	97.14	100.00	100.00	99.29
	+ 2	6.67	100.00	43.81	100.00	100.00	85.95
	+ 4	0.95	92.38	9.52	79.05	100.00	70.24
	+ 6	0.95	53.33	9.52	30.48	72.38	41.43
	+ 8	0.00	14.29	8.57	11.43	32.38	16.67
	+ 10	0.00	3.81	6.67	9.52	20.00	10.00
Tan–Triggs	0	37.14	100.00	84.76	100.00	100.00	96.19
	+ 2	0.95	37.14	0.95	80.00	100.00	54.52
	+ 4	0.95	0.95	0.00	4.76	100.00	26.43
	+ 6	0.00	0.00	0.00	0.95	100.00	25.24
	+ 8	0.00	0.00	0.00	0.00	100.00	25.00
	+ 10	0.00	0.00	0.00	0.00	80.95	20.24
Tan–Triggs + smooth	0	39.05	100.00	95.24	100.00	100.00	98.81
	+ 2	0.00	24.76	10.48	100.00	100.00	58.81
	+ 4	0.00	0.00	0.95	100.00	100.00	50.24
	+ 6	0.00	0.00	0.95	100.00	100.00	50.24
	+ 8	0.00	0.00	0.00	90.48	100.00	47.62
	+ 10	0.00	0.00	0.00	69.52	100.00	42.38
Tan–Triggs + total histogram	0	44.76	100.00	100.00	100.00	100.00	100.00
	+ 2	0.00	34.29	100.00	100.00	100.00	83.57
	+ 4	0.00	0.95	100.00	100.00	100.00	75.24
	+ 6	0.00	0.00	99.05	100.00	99.05	74.53
	+ 8	0.00	0.00	80.95	100.00	80.00	65.24
	+ 10	0.00	0.00	100.00	100.00	45.71	61.43
Tan–Triggs + total histogram + smooth	0	41.90	100.00	100.00	100.00	100.00	100.00
	+ 2	0.00	100.00	100.00	100.00	100.00	100.00
	+ 4	0.00	100.00	100.00	100.00	100.00	100.00
	+ 6	0.00	100.00	100.00	100.00	100.00	100.00
	+ 8	0.00	95.24	100.00	96.19	100.00	97.86
	+ 10	0.00	77.14	100.00	74.29	100.00	87.86

Tag ID will be used as index for a database record and the corresponding facial-features will be loaded to the face recognizer system. Afterwards, the system will capture faces using the connected webcam through USB cable for maximum time of 10 s looking for RFID Tag holder. LBP histogram would be calculated to any captured face and the resultant histogram would be compared with the already-loaded facial-features from

Table 18 Accuracies for 4 × 4 image divisions applied to collected DB images

Shift in threshold	Accuracies for 4 × 4 image divisions				
	Original (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
0	78.69	79.53	79.88	77.62	79.05
+ 2	89.64	76.79	79.41	91.79	100.00
+ 4	84.64	62.74	75.12	87.62	100.00
+ 6	70.24	62.62	75.12	87.26	100.00
+ 8	58.33	62.50	73.81	82.62	98.93
+ 10	55.00	60.12	71.19	80.71	93.93

database and generates a confidence value. This confidence value represents the distance between the saved facial-features and the features just extracted from the input image. Next, the system checks if the confidence is lower than the already set threshold, the system will confirm that the tag holder is the same person he claimed to be. Finally, the system registers any correctly classified students and the time of their attendance. In doing so, the system takes the attendance when any student enters the class, so it would not waste class time or ink and papers.

All rates have been calculated for (4 × 4) image divisions and for (8 × 8) image divisions along with the accuracies. Tables 14, 15, 16, 17 and 18 are tabulating the TP, FN, FP, TN rates and accuracy for (4 × 4) image divisions respectively, and Tables 19, 20, 21, 22 and 23 are tabulating the TP, FN, FP, TN rates and accuracy for (8 × 8) image divisions respectively.

Finally, a comparison has been done between (4 × 4) image divisions and (8 × 8) image divisions in terms of database access time, database file size per subject and average recognition time. Both experiments have the same parameters' values but differs in test subjects, see Table 24 for the comparison results. The results show that 4 × 4 image divisions gives less recognition time, less database access time, and needs less storage capacity by a factor of 3.

5 Conclusion and Future Work

This paper presented a system called Indexed Face Recognition System (IFRS), which is an access control system based on the combination of RFID technology and face recognition (Biometrics technology). From this research work the following conclusions can be drawn.

1. IFRS employees a Viola-Jones (Haar-Like) face detection method due to its speed and accuracy. Moreover, IFRS uses LBPH as a feature vector for distinguishing between different images because of its robustness against change in pose and illumination with a high computational speed.
2. In order to increase the accuracy, IFRS is enhanced with one or more of the three preprocessing techniques: Bilateral Filter, Histogram Equalization, Tan and Triggs

Table 19 TP rates of all pre-processing methods with different shift values in threshold for 8 × 8 image divisions applied to collected DB images

Shift in threshold	TP % for 8 × 8 image divisions using collected DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	40.02	45.58	40.7	45.88	34.58	37.18	34.5	37.8
0	60.00	53.34	59.00	60.00	56.19	54.28	50.58	51.43
+ 5	73.34	70.47	72.38	67.62	86.67	80.95	86.67	81.90
+ 10	81.90	75.24	86.67	76.20	95.24	95.24	97.14	97.14
+ 15	91.43	77.14	95.24	82.86	98.10	98.10	100.00	100.00
+ 20	95.24	84.76	96.19	90.47	100.00	100.00	100.00	100.00
+ 25	97.14	91.43	98.10	94.29	100.00	100.00	100.00	100.00

Table 20 FN rates of all pre-processing methods with different shift values in threshold for 8 × 8 image divisions applied to collected DB images

Shift in threshold	FN % for 8 × 8 image divisions using collected DB images							
	Threshold at different pre-processing methods							
	Original (%)	Smooth (%)	Total histogram (%)	Total histogram + smooth (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
	40.02	45.58	40.7	45.88	34.58	37.18	34.5	37.8
0	40.00	46.66	41.00	40.00	43.81	45.72	49.42	48.57
+ 5	26.66	29.53	27.62	32.38	13.33	19.05	13.33	18.10
+ 10	18.10	24.76	13.33	23.80	4.76	4.76	2.86	2.86
+ 15	8.57	22.86	4.76	17.14	1.90	1.90	0.00	0.00
+ 20	4.76	15.24	3.81	9.53	0.00	0.00	0.00	0.00
+ 25	2.86	8.57	1.90	5.71	0.00	0.00	0.00	0.00

Table 21 FP rates for the best 4 pre-processing methods that give best TP rates for 8 × 8 image divisions applied to collected DB images, FP rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	TP (%)	FP % for 8 × 8 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	60.00	20.95	19.05	0.95	0.00	10.24
	+ 5	73.34	48.57	40.00	8.57	0.00	24.29
	+ 10	81.90	72.38	60.95	24.76	0.00	39.52
	+ 15	91.43	81.90	76.19	50.48	0.00	52.14
	+ 20	95.24	93.33	83.81	66.67	0.00	60.95
	+ 25	97.14	99.05	89.52	84.76	0.00	68.33
Tan–Triggs	0	56.19	12.38	28.57	0.00	0.00	10.24
	+ 5	86.67	52.38	66.67	15.24	0.00	33.57
	+ 10	95.24	89.52	93.33	63.81	0.00	61.67
	+ 15	98.10	97.14	97.14	87.62	0.00	70.48
	+ 20	100.00	99.05	100.00	97.14	0.00	74.05
	+ 25	100.00	100.00	100.00	100.00	0.00	75.00
Tan–Triggs + smooth	0	54.28	0.95	12.38	0.00	0.00	3.33
	+ 5	80.95	17.14	45.71	0.00	0.00	15.71
	+ 10	95.24	51.43	79.05	0.00	0.00	32.62
	+ 15	98.10	79.05	93.33	0.00	0.00	43.10
	+ 20	100.00	96.19	99.05	0.00	0.00	48.81
	+ 25	100.00	99.05	100.00	0.00	0.00	49.76
Tan–Triggs + total histogram	0	50.58	7.62	0.00	0.00	0.00	1.91
	+ 5	86.67	49.52	0.00	0.00	0.00	12.38
	+ 10	97.14	88.57	0.00	0.00	0.00	22.14
	+ 15	100.00	99.05	0.00	0.00	0.00	24.76
	+ 20	100.00	100.00	0.00	0.00	0.00	25.00
	+ 25	100.00	100.00	0.00	0.00	0.00	25.00
Tan–Triggs + total histogram + smooth	0	51.43	0.00	0.00	0.00	0.00	0.00
	+ 5	81.90	0.00	0.00	0.00	0.00	0.00
	+ 10	97.14	0.00	0.00	0.00	0.00	0.00
	+ 15	100.00	0.00	0.00	0.00	0.00	0.00
	+ 20	100.00	0.00	0.00	0.00	0.00	0.00
	+ 25	100.00	0.00	0.00	0.00	0.00	0.00

algorithm. In addition, IFRS performs an image normalization processes before and after Face Detection phase to enhance images quality, these process are: Color Conversion and Image Cropping and Resizing.

3. Two experiments were done. The first experiment was done on 400 images with 40 subjects (10 images per subject). The second experiment was done on 210 collected

Table 22 TN rates for the best 4 pre-processing methods that give best TP rates for 8 × 8 image divisions applied to collected DB images, FP rates considered to 4 different DB files with different shifts in threshold value

Pre-processing method	Shift in threshold	FN (%)	TN % for 8 × 8 image divisions				
			DB file shift				Average (%)
			+ 1 (%)	+ 2 (%)	+ 3 (%)	+ 4 (%)	
Original	0	40.00	79.05	80.95	99.05	100.00	89.76
	+ 5	26.66	51.43	60.00	91.43	100.00	75.71
	+ 10	18.10	27.62	39.05	75.24	100.00	60.48
	+ 15	8.57	18.10	23.81	49.52	100.00	47.86
	+ 20	4.76	6.67	16.19	33.33	100.00	39.05
	+ 25	2.86	0.95	10.48	15.24	100.00	31.67
Tan–Triggs	0	43.81	87.62	71.43	100.00	100.00	89.76
	+ 5	13.33	47.62	33.33	84.76	100.00	66.43
	+ 10	4.76	10.48	6.67	36.19	100.00	38.34
	+ 15	1.90	2.86	2.86	12.38	100.00	29.53
	+ 20	0.00	0.95	0.00	2.86	100.00	25.95
	+ 25	0.00	0.00	0.00	0.00	100.00	25.00
Tan–Triggs + smooth	0	45.72	99.05	87.62	100.00	100.00	96.67
	+ 5	19.05	82.86	54.29	100.00	100.00	84.29
	+ 10	4.76	48.57	20.95	100.00	100.00	67.38
	+ 15	1.90	20.95	6.67	100.00	100.00	56.91
	+ 20	0.00	3.81	0.95	100.00	100.00	51.19
	+ 25	0.00	0.95	0.00	100.00	100.00	50.24
Tan–Triggs + total histogram	0	49.42	92.38	100.00	100.00	100.00	98.10
	+ 5	13.33	50.48	100.00	100.00	100.00	87.62
	+ 10	2.86	11.43	100.00	100.00	100.00	77.86
	+ 15	0.00	0.95	100.00	100.00	100.00	75.24
	+ 20	0.00	0.00	100.00	100.00	100.00	75.00
	+ 25	0.00	0.00	100.00	100.00	100.00	75.00
Tan–Triggs + total histogram + smooth	0	48.57	100.00	100.00	100.00	100.00	100.00
	+ 5	18.10	100.00	100.00	100.00	100.00	100.00
	+ 10	2.86	100.00	100.00	100.00	100.00	100.00
	+ 15	0.00	100.00	100.00	100.00	100.00	100.00
	+ 20	0.00	100.00	100.00	100.00	100.00	100.00
	+ 25	0.00	100.00	100.00	100.00	100.00	100.00

images for 21 subjects (10 images per subject) from Computer Engineering Department at University of Baghdad. The practical results show that 4 × 4 image divisions gives better results than 8 × 8 image divisions as far as recognition time, database access time, and storage capacity are concerned.

4. In general, access control systems that works in identification mode are not suitable for large organizations that have hundreds of employees because of the increasing in database size which affects response time and accuracy [9]. The proposed IFRS can

Table 23 Accuracies for 8 × 8 image divisions applied to collected DB images

Shift in threshold	Accuracies for 8 × 8 image divisions				
	Original (%)	Tan–Triggs (%)	Tan–Triggs + smooth (%)	Tan–Triggs + total histogram (%)	Tan–Triggs + total histogram + smooth (%)
0	74.88	72.98	75.47	74.34	75.72
+ 5	74.53	76.55	82.62	87.15	90.95
+ 10	71.19	66.79	81.31	87.50	98.57
+ 15	69.64	63.81	77.50	87.62	100.00
+ 20	67.14	62.98	75.60	87.50	100.00
+ 25	64.40	62.50	75.12	87.50	100.00

Table 24 A comparison between 4 × 4 and 8 × 8 image divisions in terms of database access time, database file size per subject and average recognition time for experiment Nos. 1 and 2

Image divisions	DB access time (ms)	Recognition time (ms)	Saved file size per subject (KB)
4, 4	7.8	2.25	210
8, 8	24	2.8	610

work in authentication mode and eliminates the dependency between the response time and database size because the access time and response time are fixed in authentication mode. Furthermore, IFRS provides a very high accuracy that reaches 100%.

5. IFRS gives the highest accuracy when applying all of the three pre-processing methods altogether: Bilateral Filter, Histogram Equalization, Tan and Triggs algorithm.
6. IFRS proves that it can be adopted in real-time applications applied to large organizations having hundreds or even thousands of employees without affecting system performance.
7. In addition to the high accuracy that IFRS produces, IFRS is considered as a low-cost access control system as compared to other access control systems having an equivalent performance.

From the above, and more importantly, the research contribution has been achieved by applying a (1:1) relationship. In doing so, IFRS hits the two faces for the same coin (i.e., provides a very high accuracy with a very little amount of time delay).

The future works can be listed as follows.

1. A writable RFID tag can be used for the authentication process so that RFID tag would keep the threshold value (used in the classification phase) saved in it to be used when applying RFID tag to the reader. Hence, the accuracy would be increased if a different threshold is been used for different subjects instead of using the shifted average threshold.
2. Further study for adopting another LBP based feature extraction method by using only uniform patterns [18, 19] in LBP operator. Using only uniform patterns will decrease the database size; however, a comparison should be done between using uniform patterns results and IFRS results in terms of accuracy and time delay.

3. Studying the possibility of adopting IFRS in high-sensitive applications such as ATM machines. With such applications, IFRS needs to be enhanced with some privacy and security algorithms. IFRS can be used for authentication process instead of using the regular PIN in ATM machines which is very easy to be hacked or forgotten.

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