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An improved face recognition algorithm and its application in attendance management system

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A R T I C L E I N F O

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A B S T R A C T

Face Recognition is a computer application that is capable of detecting, tracking, identifying or verifying human faces from an image or video captured using a digital camera. Although lot of progress has been made in domain of face detection and recognition for security, identification and attendance purpose, but still there are issues hindering the progress to reach or surpass human level accuracy. These issues are variations in human facial appearance such as; varying lighting condition, noise in face images, scale, pose etc. This research paper presents a new method using Local Binary Pattern (LBP) algorithm combined with advanced image processing techniques such as Contrast Adjustment, Bilateral Filter, Histogram Equalization and Image Blending to address some of the issues hampering face recognition accuracy so as to improve the LBP codes, thus improve the accuracy of the overall face recognition system. Our experiment results show that our method is very accurate, reliable and robust for face recognition system that can be practically implemented in real-life environment as an automatic attendance management system.

1. Introduction

The human face is a sophisticated multidimensional structure that can convey a lot of information about the individual, including expression, feeling, facial features. Effectively and efficiently analyzing the features related to facial information is a challenging task that requires lot of time and efforts. Recently, many facial recognition-based algorithms for automatic attendance management has been proposed, successfully implemented and used as in Refs. [1–4] and also new algorithms developed or some existing algorithms improved or combined with other methods, techniques, or algorithms to build facial recognition systems or applications as in Refs. [5–8].

Although lot of achievements have been made in devising facial recognition algorithms and systems, but to reach human level accuracy of facial recognition, some major issues associated with these algorithms/systems should be greatly mitigated or addressed as argued in Ref. [9] so as to realize a reliable and accurate facial recognition-based automatic attendance management system, which can be very useful in the area of substantiation.

The main challenges for successful face detection and recognition systems are; illumination conditions, scale, occlusion, pose, background, expression etc., as highlighted in Refs. [10,11]. Various algorithms and methods have been proposed to address these challenges; N.Pattabhi Ramaiah Ref. [12] uses illumination Invariant Face Recognition using Convolutional Neural Networks to address illumination conditions, Abass et al Ref. [13] addresses the issues of shift and rotation using complex wavelet transform (CWT) and Fisherface. To address issues related to pose, Kishor et al Ref. [14] proposes robust pose invariant face recognition using Dual Cross Pattern (DCP), LBP and Support Vector Machine (SVM).

In our research work, which is divided into two main sections: The first section focused mainly on improving the face recognition algorithm while the second section focused on the attendance management system based on the recognized human faces. In the first section, a digital live camera will be used at the entrance to capture images of staffs entering an office or a building, which some advanced image processing techniques, such as contrast adjustment, noise reduction using bilateral filter, image histogram equalization, are applied to the captured images to improve their quality, then the Haar Algorithm will be applied to the captured images to detect individual faces, which will be used as an input to the Face Recognition System.

And also the same advanced image processing techniques above, plus Image Blending technique will be applied, a prior, to the training/template face images, then the improved input images will be compared with the improved training images using the LBP algorithm, to yield an improved LBP codes to recognize faces, thus the facial recognition

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accuracy will be improved compared to the traditional LBP codes without our method. In the second section, the metadata of the recognized facial images such as date and time are automatically extracted to automatically mark attendance of each individual.

2. Related work

Kohonen Ref. [15] is one of the early pioneers of the most famous face recognition system, which employed a simple neural net using network of Eigenfaces by approximating eigenvectors through face images auto-correlation matrix. Although, the method was not very successful to be practically implemented in a real-life environment due to associated high demand for normalization and positioning when run in a large database with many types of face conditions.

In harnessing and improving the work of Kohonen, Kirby and Sirovich in 1990 as in Ref. [16], directly calculated the Eigenfaces using algebraic manipulation with fewer than 100 faces to implement facial recognition, which was further improved by Turk and Pentland in 1991 as in Ref. [17] by determining the exact location and scales of faces and also the use of coding residual error originated from Eigenfaces, but in a minimally constrained environment.

Better and more novel approaches than Kohonen approach for facial recognition using; Principal Component Analysis (PCA), Fisherfaces and the traditional Local Binary Patterns (LBP) were proposed, particularly the LBP, because it has a simple theory with computational simplicity, invariant with respect to any monotonic transformation of gray scale, has powerful rotation-invariant analysis with a uniform pattern and discriminates excellently between different various kinds of texture as in Ref. [18], but It is known that the LBP is not as robust as the viola-jones and other algorithms for face detection as highlighted in Refs. [19–21], because of issues such as noise, illumination variation, background, pose, scale and occlusion etc.

In addressing the issue of illumination variation, Ref. [22] mitigated illumination variation in facial recognition by combining the strengths of robust illumination normalization, local texture-based face representations, distance transform based matching and kernel-based feature extraction and multiple feature fusion, but the solution addressed only illumination issues. To address issues of noise in facial recognition, Ref. [23] employed shearlets and LBP for dealing with heavy noise in face recognition, by taking advantage of robust features and edge detection capabilities of shearlets in the presence of high level of noise. In this method, each face is divided into blocks, individual classifier is used for each block and then combine the similarity scores from all the blocks for better performance, but the solution is limited to noise only.

Recently, different methods, techniques and algorithms were combined with either the traditional LBP or modified LBP to achieve facial recognition and enhance facial recognition accuracy. In Ref. [24] a Real-Time Multiple Face Recognition using Deep Learning on Embedded GPU System was proposed and the method used face detection based on convolutional neural network (CNN) with face tracking and state of the art deep CNN face recognition algorithm.

In addition, in Ref. [25] a Local Binary Pattern Histogram (LBPH)-based Enhanced Real-Time Face Recognition was used to achieve real-time face recognition in low and high-level images and Ref. [26] proposes a method of Improving the Recognition of Faces using LBP and SVM Optimized by PSO Technique, in this method, two feature extraction algorithms namely Principal Component Analysis (PCA) and Local Binary Pattern (LBP) techniques are used to extract features from images. In the recognition process, it uses Support Vector Machine (SVM) for classification combined with Particle Swarm Optimization.

In another approach in Ref. [27], facial recognition was achieved using Modified Local Binary Pattern and Random Forest, which the sign and magnitude features are combined for the improvement of facial texture classification performance and when compared with the traditional LBP for multiple patch variations on a challenging facial dataset, this method proven to be more accurate.

All these techniques, methods, algorithms reviewed does not wholly addresses issues affecting facial recognition accuracy such as illumination variation, noise, scale, sharp, pose in one shot, while our method was able to do that and also our method focuses on enhancing features of input and training images, thus improved LBP codes and achieved better recognition results.

3. Improved LBP algorithm

In our work, we acknowledge the fact that capability of the LBP face recognition algorithm highly depends on the accuracy performance of feature extraction and comparison stage, which also highly depends on the quality of both the input face images and the training/reference images participating in the face comparison process. In order to improve the face recognition accuracy of the LBP algorithm, we exploited the following image quality properties of our input and reference face images: illumination, sharp, noise, resolution, scale and pose, so as to obtain the best quality images that will expose better details of image features for more accurate feature extraction and comparison.

3.1. Proposed methodology

Our first improvement approach is to apply the Contrast Adjustment method on our input face images as defined in equation (1). We tested this method with different values of alpha and beta to select the one that gives the best detection and recognition accuracy result, which are 1.5 (α) value and 0.0 (β) value.

$$g(x, y) = \alpha * f(x, y) + \beta \tag{1}$$

In the second approach, we compared effects of these three types of filters: Gaussian Blur Filter, Median Filter and Bilateral Filter on the accuracy performance of our face recognition system. We selected the filter

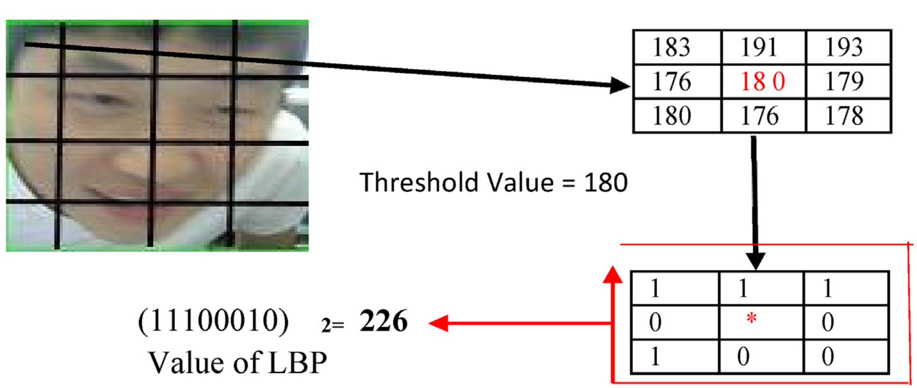


Fig. 1. The original LBP operator.

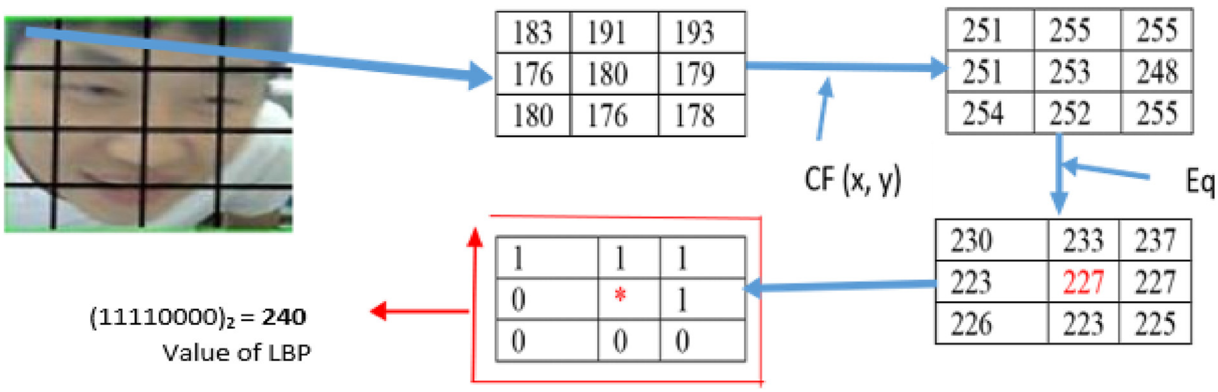
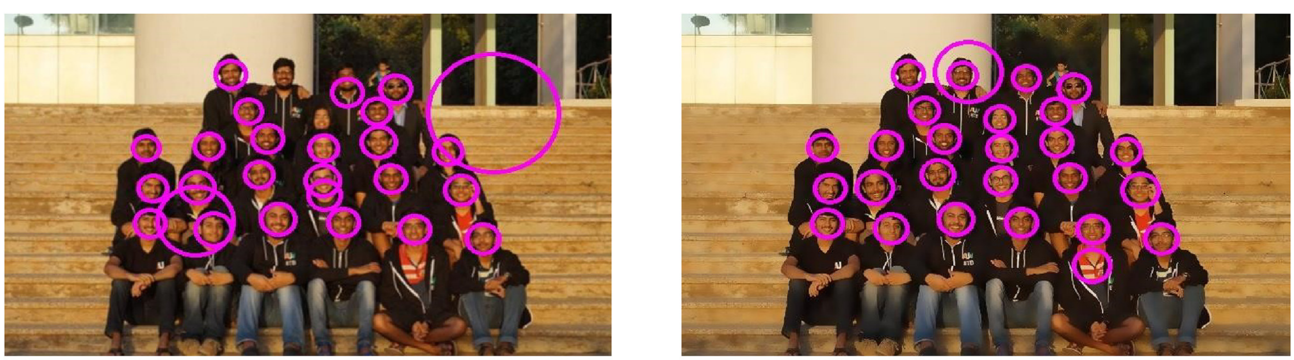


Fig. 2. The modified LBP operator.

(a) Original Image (b) Contrasted Image (c) Filtered Image (d) Equalized Image

Fig. 3. Shows the original image and processed images defined in equations (1)–(4)



(a) Face detection using Haar Classifiers **(b) Face detection using our improved LBP**

Fig. 4. Shows detected faces using the Haar cascade classifiers and LBP cascade classifier aided with our proposed methods defined from equation (1) to equation (4).

Table 1
Face detection evaluation result.

	Total Faces	Haar	LBP	Proposed Method
True Positive	226	208	206	**215**
False Positive	226	18	20	**11**
False Negative	226	55	41	**33**
Detection Accuracy Rate		**92%**	**91%**	**95%**

that gives the best result in our case, which is the bilateral filter as defined in equation (2).

$$F(x,y) = \frac{\sum_{x=-N}^{N}\sum_{y=-N}^{N} I(x,y)W(x,y)}{\sum_{x=-N}^{N}\sum_{y=-N}^{N} W(x,y)} \tag{2}$$

where $W(x,y)$ is the filter weighting function, $I(x,y)$ is the input face image neighborhood pixel and the denominator is the normalization of the weighting function, and $F(x,y)$ is the result of the bilateral filter applied on a $2N+1$ neighborhood. Now we defined $CF(x,y)$ in equation (3) as the function to reduce noise and control contrast effects in the input images, where $g(x,y)$ in equation (3) is the contrasted image and $F(x,y)$ is the applied filter.

$$CF(x,y) = g(x,y)^{*}F(x,y) \tag{3}$$

The resultant image pixels derived from the above equation are equalized using the image histogram equalization method defined in equation (4) to finally address the global lightning issues in the processed facial images.

$$Eq = H'(CF(x,y)) \tag{4}$$

where H' is the normalized cumulative distribution with a maximum value of 255 as in Ref. [28], finally, we applied the LBP algorithm on our

Fig 5. Blending two different images.

Table 2
Shows the performance evaluation of original LBP operator using **dataset [I]**.

Total Faces	False Negatives	Unknown Faces	False Recognition
355	18	1	32
357	6	3	24
363	27	0	37
417	7	4	49
371	10	5	35

Face Recognition Rate = 90.49%.

Table 3
Shows the performance evaluation of improved LBP algorithm using **dataset [III]**.

Total Faces	False Negatives	Unknown	False Recognition
764	1	5	1
773	0	8	0
765	0	13	0
760	0	9	1
762	2	4	0
768	0	3	1
767	0	8	1

Face Recognition Rate = 99%.

detected face images for feature extraction & comparison. The first LBP operator described in literature uses a fixed 3 X 3 neighborhood window, as shown in Fig. 1 below:

A more formal description of the LBP operator can be given as follows in equation (5):

$$\text{LBPp, r}(X_c, Y_c) = \sum_{p=0}^{p-1} 2^p \text{S}(i_p - i_c) \tag{5}$$

where (X_c, Y_c) is gray-level value of the center pixel with i_p and i_c being the intensity of the neighbor pixel and p the surrounding pixels in the circle neighborhood with a radius r, and $S(\text{X})$ is the sign function defined in equation (6), it's used to threshold the fixed 3 X 3 neighborhood as in Ref. [29].

$$S(\text{X}) = \begin{cases} 1 & \text{if} \quad x \geq 0 \\ 0 & \text{if} \quad x < 0 \end{cases} \tag{6}$$

In our approach, we demonstrated the effect of using equations (1)–(4) to improve the overall quality of our input face images so as to boost the accuracy performance of the LBP face recognition algorithm as shown in Fig. 2 below.

Examining each window of the 3 × 3 neighborhood pixels of the resultant images from equations (3) and (4), the issues of noise, illumination, sharp, and resolution were highly mitigated. We obtained higher pixel and threshold values as shown in Fig. 2, after applying equations

Table 4
Face recognition accuracy methods comparison.

Methods	Accuracy (%)
LBP + SVM + PSO [26]	96.54
Original LBP [33]	89.3
DCP + LBP + SVM [14]	97.50
Proposed Method	99.0

Table 5
Shows database attendance records.

ID	Name	Time_In	Time_Out
1	Modou Bah	6/16/2016 09:24	6/16/2016 13:48
2	Wang Long	6/16/2016 09:31	6/16/2016 13:49
3	Tian Ying	6/16/2016 09:37	6/16/2016 13:48
4	Mrs.Wudan	6/16/2016 09:38	6/16/2016 13:47

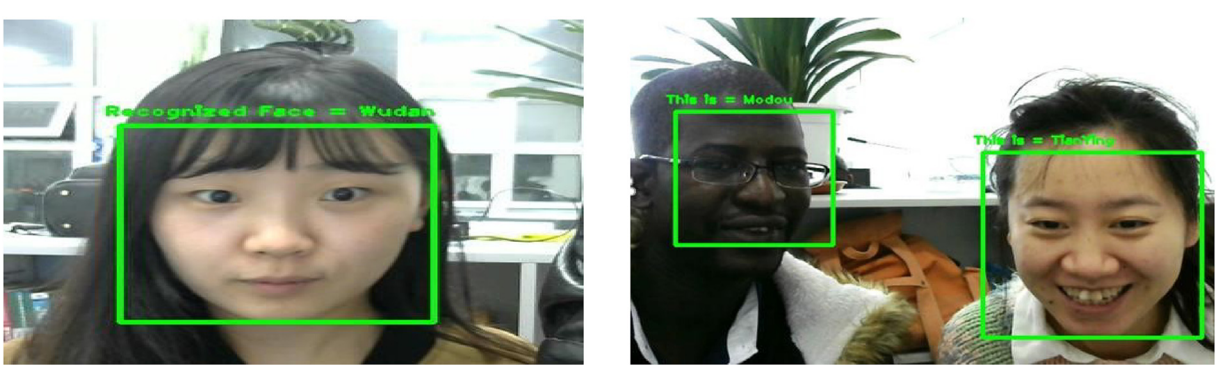


Fig. 6. Face recognition results.

(1)–(4) to the original input images, we obtained an improved high quality images using our method, which implies better image quality that will expose better image features and enabled more accurate image histograms for facial image comparison as shown in section 4, Fig. 3 (a) to (d), thus resulted in an improved LBP codes, that will stimulate the overall face recognition accuracy.

4. Experiments

In this research paper, we present an effective and efficient approach using advanced image processing techniques to improve face recognition accuracy based on local binary patterns algorithm. In this section, we'll give experiment results from two interconnected parts to demonstrate our method.

In the first part, the LBP cascade classifier is employed for multiple face detection and tracking. first, we'll capture faces from a live digital camera or sourced from a digital image and apply the LBP cascade classifier algorithm to detect faces. To improve the accuracy of the LBP face detection algorithm to the level of Haar cascade classifier face detection algorithm as in Ref. [30] or even better while maintaining speed, we used image processing techniques defined in equations (1)–(4).

Our experiment result for this part is shown in Figs. 3 and 4 and Table 1. Using our approach, we were able to improve the face detection accuracy rate, which is an integral part of the overall face recognition accuracy rate, while at the same time reducing the number of false positives and false negatives.

In this experiment, the Haar classifier algorithm is used to detect faces in an image as shown in Fig. 4 (a). The Haar classifier algorithm consist of four (4) phases; integral image, Haar-like features. AdaBoost and Cascading Classifier, in which the input face images will be represented as integral images first, to compute Haar-like features, for optimization reason, the AdaBoost will be used for feature selection, then the selected features will be passed through a cascading classifier to classify faces in an image.

Aside the Haar Classifier algorithm, our proposed improved LBP method is also used to detect faces in an image as shown in Fig. 4 (b). Comparing the two methods in Fig. 4, it is shown that our proposed method outperformed, the Haar Classifier algorithm for Face Detection and also in the number of detected faces, represented as true positive or false positive, represented as features that are incorrectly detected as faces or false negative, represented as faces that are not detected as faces in an image. In Table 1, for face detection, the Haar algorithm, the original LBP and the improved LBP using our method are compared using a dataset of 226 images, which our method perform better in all cases.

4.1. Linear blending of training images

After the face detection process, we'll use the LBP algorithm aided with the advanced image processing techniques defined from equation (1) through equation (4), to better extract facial features so as to compare and recognize human faces.

In the second part, before applying the LBP face recognition algorithm on detected face images, we employed image blending technique on our training images datasets. Image blending is a linear interpolation often used to blend two images f_0 and f_1 as shown in Fig. 5, in order to improve the visual quality of images by minimizing intensity variations effects. The linear blending is defined in equation (7), where (α) and (1-α) are blend fractions used in a weighted average of each component of each pixel as highlighted in Refs. [31,32].

$$G(x) = (1-\alpha)f_0(x) + \alpha f_1(x) \tag{7}$$

In our work, we created three different datasets each containing different orientations and conditions of faces that are confined to 181 × 181 pixels: **dataset [I]**, **dataset [II]**, and **dataset [III]**. No image blending was applied in the dataset [I], the linear blending of 1.0 alpha (α) was applied on dataset [II], and linear blending of 0.5 alpha (α) was applied on dataset [III]. We tested the improved LBP face recognition algorithm on these three datasets and selected the one that gives the best face recognition accuracy result in our system, which is dataset [III]. Prior to confining the training images to 181 × 181 pixels, we empirically tried different pixel values on the training datasets to check whether it will have any impact on the face recognition accuracy, which it does, although the impact is not that much, but the best result was selected, which is 181 × 181 pixels.

We improved the quality of both our input face images and training images, using our proposed methods defined in equations (4) and (5). Now we apply the LBP algorithm aided with our methods to extract more detailed and visible facial features to increase comparison certainty for more accurate face recognition.

In Table 2, we show the performance evaluation of the original LBP algorithm that was run on our dataset [I], the dataset without any image processing. We used the following metrics in our evaluation: False Negatives, Unknown faces, and False Recognition. We calculated the face recognition rate as follows: **Face Recognition Rate** = (*Total Number of Faces - a total number of False Recognition)/(Total number of Faces) * 100%.*

In Table 3, we show the performance evaluation of our improved face recognition method using equation (3) and (4) that was run on our dataset [III], which was processed using equation (7) with an alpha (α) value of 0.5. Using the same metrics and face recognition rate formula above. Fig. 6 below shows the result of recognized faces of three (3) different people.

In addition, In Table 4, the face recognition accuracy of our proposed method is compared with three (3) other different existing methods in a controlled environment, respectively.

The results in Table 4, shows that our method compared to other different methods, proves to be very robust to be implemented in a controlled real-life environment and the novelty of our method is centered towards the combination of the LBP algorithm with advanced image processing techniques such as contrast adjustment, bilateral filter, histogram equalization and image blending for both input images and training images, which is more of incremental contribution to the LBP improvement.

5. Attendance system

After successfully recognizing human faces, the recognized face images will be fetched into our attendance system to mark attendance of individuals.

5.1. Attendance database

In our attendance database, we will extract each recognized face images to mark the attendance of individuals, using date and time educed from recognized face images as shown in Table 5.

5.2. Flowchart of algorithm

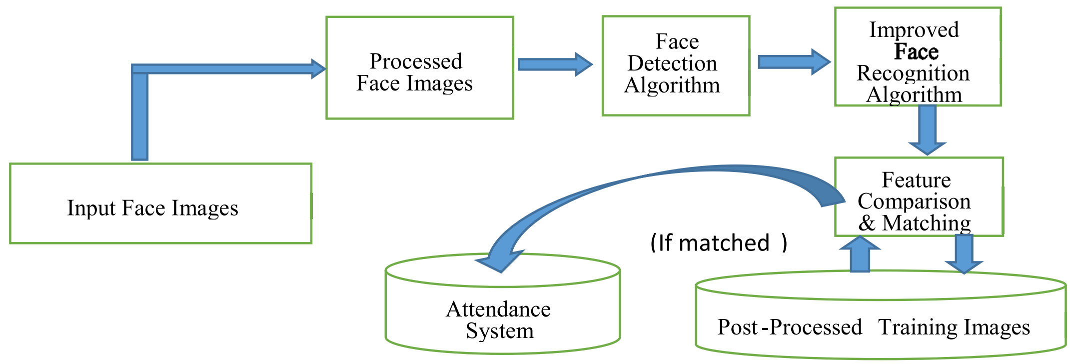


Figure shows the flowchart of the algorithm. As depicted in the flowchart, the captured input face images are processed using our proposed image processing techniques, then the face detection algorithm is applied to detect faces. Once faces are detected, the face recognition algorithm aided with our proposed method will be applied to recognize faces. Once faces are recognized, the metadata of the recognized faces will be extracted to mark attendance using the attendance system.

6. Conclusion

In conclusion, in our research, after preprocessing the input face images using some advanced image processing techniques such Contrast Adjustment, Bilateral Filter, Histogram Equalization, so as to have better image features and the same advanced image processing techniques will be applied to the training/template face images plus an image blending method to ensure high quality training/template face images. The preprocessed input face image will be divided into k^2 regions, then the LBP code will be calculated for every pixel in a region of the input face image by comparing the center with the surrounding pixel. If the surrounding pixel is greater than or equal to the center pixel, then it is denoted as binary 1, else it is denoted as 0.

This process will be repeated for each and every pixel of all other regions, to get the binary pattern so as to construct the feature vector of the input face images. For every region, a histogram with all possible labels is constructed. These constructed histograms with all its bins represent a pattern and contain the number of its appearance in the region. The feature vector formed is then constructed by concatenating the regional histograms to one big histogram, which is unique for each individual, and is compared with the template face images to recognize faces. This method improves the LBP code and our experiment results show that our method is very accurate and robust for facial recognition system that can be implemented in a real-life environment. It is also important to state that our research does not address the issue of occlusion and mask faces in facial recognition, but addressing these issues could be a perfect future work of this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.array.2019.100014.

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