Face Recognition with Local Binary Patterns

Ammad Ali, Shah Hussain, Farah Haroon, Sajid Hussain and M. Farhan Khan

Abstract- This paper is about providing efficient face recognition i.e. feature extraction and face matching system using local binary patterns (LBP) method. It is a texture based algorithm for face recognition which describes the texture and shape of digital images. The preprocessed or facial image is first divided into small blocks from which LBP histograms are formed and then concatenated into a single feature vector. This feature vector plays a vital role in efficient representation of the face and is used to measure similarities by calculating the distance between Images. This paper presents the principles of the method and implementation to perform face recognition. Experiments have been carried out on Yale data set; high recognition rates are obtained, especially compared to other face recognition methods. Also few extensions are investigated and implemented successfully to further improve the performance of the method.

Index Terms: Face recognition, Local Binary Pattern, Illumination normalization.

I. Introduction

Face Recognition, as the name suggests, is a method to identify and/or verify the identity of a person. In the former process, the preprocessed image of a person is compared with face images of known individuals from a large database, the algorithms then returns the recognized (and of course correct) identity. While in the later process the preprocessed image of a person is compared with one face image from a database with the claimed identity. The system then returns the verification status by measuring the similarities between the two images. An efficient face recognition system could replace current identification methods like Personal Identification Number (PIN)-codes, passwords and Identification-cards, which according to [1],[2] could be exposed to security attacks, but also extremely reliable methods of biometric person identification, like fingerprint analysis [3] and retinal or iris scans [4]. In contrast, face recognition system is more proficient, accurate and reliable than all the proposed algorithms thus far.

The evolution in the field of pattern analysis and computer vision has now opened new horizons for research in commercialized face recognition systems being used by (PCA) [6], Linear Discriminant Analysis (LDA) [7] and the more recent 2-D PCA [8] proffer consistent results in precise environment but have limitations when variation in several factors occur.

various organizations [5]. Different comprehensive feature extraction methods such as Principal Component Analysis

Mostly they are less accurate due to lightening (and pose) changes and due to variation in facial disguise such as variations in hair style, beard, moustache, lips, eye brows, view point, facial expressions, lightning changes and further more wearing glasses, cap and hat.

The goal of this paper is to minimize the influence of these factors and design a robust face recognition system. To achieve this scope, LBP technique has been used for the purpose of feature extraction. Also illumination normalization has been implemented through Single Scale Retinex (SSR) algorithm [9], [10] to further improve the performance of the face recognition system. Rank curves are drawn after implementing SSR algorithm and improvements have been observed in recognition rate.

A face recognition system is normally implemented in three stages and is shown in Section II. Section III is especially dedicated to LBP, its methodology and making use of the uniform LBP and its descriptors. Section IV is about added extension i.e. normalizing the illumination changes by implementing SSR algorithm. Experiments that has been carried out in MATLAB on 'Yale dataset' are described in section V, results before and after implementing the added extension are also shown is this section.

II. Typical Face Recognition System

A face recognition system is used to identify and/or verify the identity of a person from a digital image. To identify a face using face recognition system, a digital image passes through three main phases i.e. face detection, feature extraction, and face recognition [11] (Fig 1). The face detection block separates the facial area from the rest of the background image. In the feature extraction phase, the most useful and unique features (properties) of the face image are extracted. Once these features are obtained then in recognition phase, the image is then compared with the images in different classes. The image with least distance with the images in classes gets highest matching score and is said to be identical image.

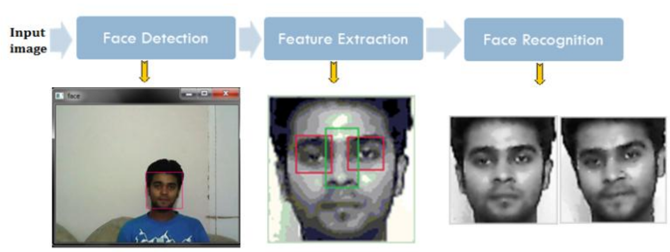

Fig.1. Typical face recognition system

Ammad Ali, Shah Hussain, Farah Haroon, Sajid Hussain IIEE, NED, Muhammad Farhan Khan Nust, PNEC Karachi, Pakistan. taurianboy90@gmail.com. Manuscript received March 21, 2012; revised May 23, and October 19, 2012.

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III. LOCAL BINARY PATTERN

Face recognition i.e. feature extraction and face matching in this paper has been carried out by LBP method. LBP was introduced by Ojala et al. [12] in 1996, is described as *an ordered set of binary comparisons of pixel intensities between the center pixel and its surrounding pixels.* It is used for extracting unique and useful features from preprocessed images and is the most efficient and newest approach for face recognition. With LBP it is possible to describe the texture and shape of a digital image. Each pixel of an image is labeled with an LBP code which is obtained by converting the binary code into decimal one. First it will divide the image to several small blocks from which the features are extracted (Fig 2). Then it will start calculating the LBP histograms for each block from the obtained features. After that it will combine all LBP histograms for that image to obtain one concatenated vector. Images can then be compared by measuring the similarity (distance) between their histograms. Several studies and research work [13], [14], [15] indicates that face recognition using the LBP method provides very good results with different facial expressions, different lightening conditions, image rotation and aging of persons. Speed and discrimination performance of an LBP system is also magnificent.

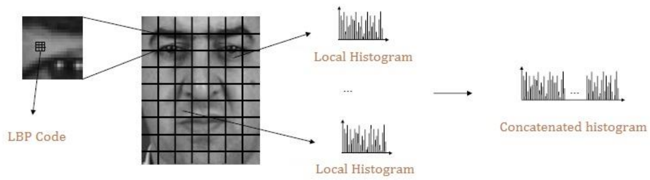

Fig. 1. Face image divided into 63 regions, with for every region a histogram and then a concatenated histogram.

Although the LBP method was initially adopted for face identification and face verification, it has already taken place in numerous applications all over the world. Number of extensions and improvements has been developed in the past few years and a lot of research is still ongoing to improve the robustness of the method.

A. Uniform Local Binary Pattern:

An important special case of LBP is the uniform LBP. *A uniform LBP descriptor contains maximum two bitwise transitions from 0 to 1 or vice versa.* Since the allotted binary string needs to be considered circular, therefore the occurrence of only one transition in the LBP descriptor is not possible. This means that a uniform pattern has either no transitions or two transitions. 11111111 and 10001111 are the examples of uniform binary patterns with zero bitwise transitions and two bitwise transitions respectively. If P is the total number of sampling points on the edge of the circle, then according to [14] possible combinations for patterns with two bitwise transitions are calculated by $P(P-1)$ which makes it a lot less and hence easy to work with as compared to non-uniform patterns which has possible combinations of 2^p. Another reason why uniform LBP should be used is that it detects only the most important features in the preprocessed images such as corners, spots, edges, and line ends as shown in Fig 3.

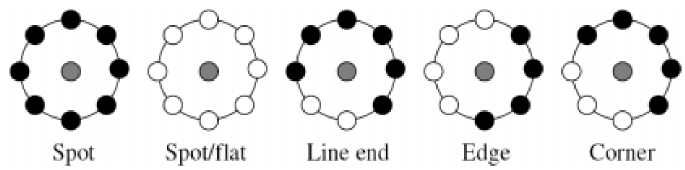

Fig. 2. Different texture primitives detected by the LBP operator.

B. LBP operator

As described, the original LBP operator was designed to work with only eight neighborhood pixels with a radius of just one pixel, denoted by $LBP^{u2}_{8,1}$[1](Fig 4). Later to improve the length of the feature vector different operators were introduced by researchers. With these extended operators neighborhood pixel or sampling points of different sizes can be chosen. According to [13] $LBP^{u2}_{16,2}$(sixteen neighborhood pixels with radius of 2 pixels) and $LBP^{u2}_{8,2}$ (eight neighborhood pixels with radius of 2 pixels) gives the best results on most databases. In this paper experiments have been carried out on these two operators along with the original operator.

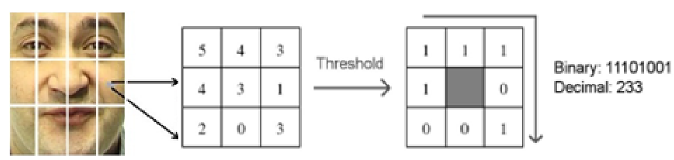

Fig. 3. The original LBP operator.

C. Region Sizes

The length of the feature vector depends on the blocks that the image has been divided into. For example, m number of blocks will make a feature vector m times larger.

D. Mathematical Module:

To use neighborhoods of different sizes LBP operator was extended by drawing circle with radius R from the center pixel. P number of sampling points on the edge of this circle are taken and compared with the value of the center pixel. Three neighborhood-sets for different values of P and R are shown in (Figure 5).

[1] The notion $LBP^{u2}_{8,1}$ is used to represent uniform patters with eight neighborhood pixels and radius of one pixel. Generally the former one is denoted by P and the later by R.

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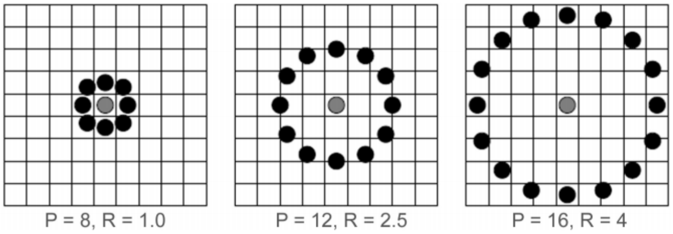

Fig. 4. Circularly neighbor-sets for three different values of P and R.

According to [16] if the coordinates of the center pixel are (x_c, y_c) then the coordinates of his P neighbors (x_p, y_p) on the edge of the circle with radius R can be calculated by Equation (1) and Equation (2), where P represents the total number of sampling points and p refers to each individual sample point.

$$x_p = x_c + Rcos\left({}^{2\pi p}/_{P}\right) \quad (1)$$

$$y_p = y_c + Rsin\,({}^{2\pi p}/_{P}) \quad (2)$$

Equation (3) [16] is used to produce the LBP for pixel (x_c, y_c) in which a binomial weight 2^P is assigned to each sign $\sum_{p=0}^{p-1} s(g_p - g_c)$. These binomial weights are summed as:

$$LBP_{P,R(X_C,Y_C)} = \sum_{p=0}^{p-1} s(g_p - g_c)2^p \quad (3)$$

Finally Chi-squared statistics (χ2) [17], as mentioned in Equation (4), is used to compare two face images, a sample (S) and a model (M), which measures the difference between the feature vectors.

$$x^s(S,M) = \sum_{j=1}^{k^2}\left(\sum_{i=1}^{p(p-1)+3}\frac{(S_{i,j}-M_{i,j})^2}{(S_{i,j}+M_{i,j})}\right) \quad (4)$$

Where $S_{i,j}$ and $M_{i,j}$ represent the sizes of bin i from region j. This weighted χ2 for two (preprocessed/face) images, which is calculated from the histograms, is a measure for the similarity between these images. The lower the value of the χ2 (which is also called the 'distance' between the two images), the more it gets near to be 'identical'.

IV. Added extension based on experiments

The major problem with face recognition system is to deal with the illumination changes [18] and pose variations. The occurrence of these changes can cause serious problems in performance of a facial recognition system. Mostly differences in images induced by illumination are larger than differences between individuals, which off course is a serious problem. In this paper experiments have been carried out to test and improve the performance of the LBP-method by normalizing these changes. Improvements have been observed with the added extension.

A. Illumination Normalization

Illumination reduction has been carried out, to remove the lightening changes, through SSR algorithm [9],[10]. SSR passes a digital image through a low pass filter. In this experiment Gaussian filter [19] is used as a low pass filter. According to [20] Digital images actually are composed of two frequency components i.e. illumination (low frequency component) and reflectance (high frequency component), where illumination factor needs to be removed.

$$f(x,y) = I(x,y)R(x,y) \quad (5)$$

(a) **(b)**

Fig. 5. (a) Image before applying the SSR algorithm. (b) Image after applying the SSR algorithm

Where (x, y) are the coordinates of a digital image, I is the illumination factor in a digital image and R represents the reflectance factor.

Equation (6) represents the mathematical module to implement SSR.

$$R = Log\big(f(x,y)\big) - Log\big(f(x,y)\big) * T(x,y) \quad (6)$$

Where $f(x,y)$ represents the actual digital image, $T(x,y)$ is Gaussian low pass filter to bypass the low frequency component from the actual image which mathematically can be represented by Equation (7). Here c stands for standard deviation and the results in this paper are obtained by setting standard deviation to 30.

$$T(x,y) = e^{{}^{(-x^2-y^2)}/_{c^2}} \quad (7)$$

In Equation (6) the real image is convoluted with a low pass filter so that only the low frequency component i.e. illumination factor is bypassed. Then this convoluted result is subtracted from the real image and the output is an image with illumination factor being reduced.

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V. EXPERIMENTS AND RESULTS

The LBP method Implementation has been carried out in MATLAB on different kind of images taken from 'Yale data set' [21] to test the performance of the method. Sampling points and radius of the LBP operator are varied to observe the influence of these parameters on the performance. Experiments after applying the extension i.e. SSR algorithm are also done, high recognition rates are observed, as compared to the results obtained without applying SSR algorithm.

The preprocessed images and possibly the training data are fed into the experimental algorithm where with the LBP method the feature vector for every image is produced. By using Chi-squared statistics ($\chi 2$) it calculates a distance matrix containing a measure for the similarity (the distance) between each pair of images. Then by using the distance matrix and the given gallery image and probe image lists, the system calculates the rank curves. A rank curve is a cumulative matching score for the probe images with the gallery images. The recognition rate is plotted as a function of the rank in a sorted list of scores. E.g. rank 1 refers to first minimum distance, rank 2 to second minimum distance, and rank 3 to third minimum distance of the probe image with the images in dataset.

Experiments are carried out with the Yale data set which is characterized by strong variations of expression and lighting. This task is therefore more complex and the results are relatively worse as compared to other standard data sets. Rank curves are drawn with the non-weighted version of $LBP^{u2}_{8,1}$, $LBP^{u2}_{16,2}$ and $LBP^{u2}_{8,2}$.

A. *Rank curves before applying SSR algorithm*

Figure 7 illustrates that the accuracy of $LBP^{u2}_{8,1}$at rank 1 is 25% and it$_s$ maximum accuracy i.e. 93% is achieved at rank 6. The $LBP^{u2}_{8,2}$ achieve 100 percent accuracy at rank 13 and its accuracy is 47% at rank 1. Whereas the $LBP^{u2}_{16,2}$ achieve its 100 percent accuracy at rank 9 and at rank 1 its accuracy is 47%. So it's concluded that the $LBP^{u2}_{16,2}$ operator gives the best results among them.

B. *Rank curves after applying SSR algorithm*

After SSR is implemented on the Yale data set, improvements have been observed. Figure 8 illustrates that there's no improvement in the performance of $LBP^{u2}_{8,1}$ operator after the added extension, in fact it had gone a bit worse after few ranks. Some improvements have been observed in the performance of $LBP^{u2}_{8,2}$ operator, its accuracy has gone better especially at lower rank values. Whereas high recognition rates of $LBP^{u2}_{16,2}$ are obtained especially at rank 7.

VI. CONCLUSION

This research paper is about designing and implementing an efficient face recognition system which

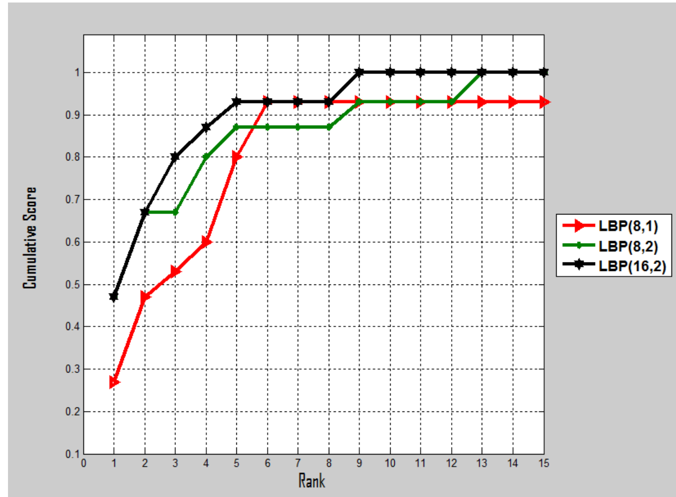

Fig. 6. Rank curves before normalizing the illumination factor.

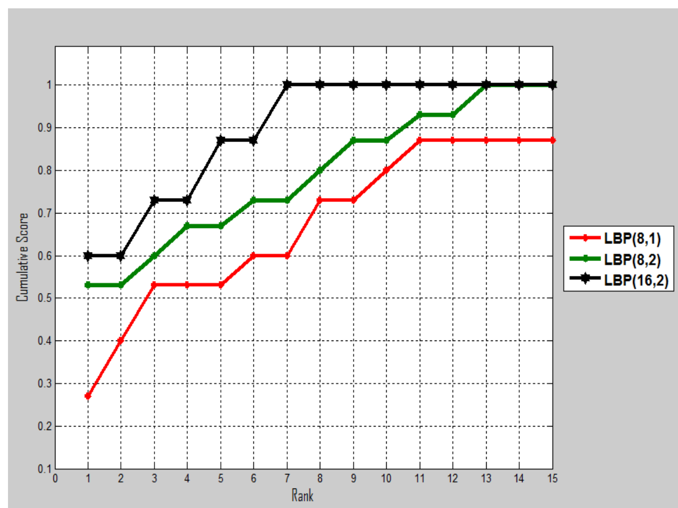

Fig. 7. Rank curves after normalizing the illumination factor

performs well under structured surrounding. Extensions have also been made to make the performance of the system effective in relatively unorganized surrounding. Unorganized surrounding mostly refers to lightening and pose variations and facial disguise. In this research work lightening changes are normalized by implementing SSR algorithm which removes the illumination factor from the actual image, hence making it easy for the feature extraction algorithm to correctly match it with the most similar face image in the database. Rank curves are also drawn with different operators of uniform LBP by taking face images from the standard Yale data set. The rank curves showed that the $LBP^{u2}_{8,1}$ operator achieves its maximum accuracy before the others but does not achieve

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100 percent accuracy at all. Whereas the $LBP^{u2}_{16,2}$ operator achieves its 100 percent accuracy in fewer rank value as compared to $LBP^{u2}_{8,2}$. After normalizing the illumination factor, much improved results are obtained at $LBP^{u2}_{16,2}$ operator. Therefore it's concluded that the performance of a recognition system can be improved by applying SSR algorithm and using $LBP^{u2}_{16,2}$ as the LBP operator.

These results can be further recuperated by using weighted LBP in which weights are assigned to each region of the face. The more important the characteristics of the region, the highest weight are assigned to that region, hence making it more proficient to distinguish between images.

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