

A Novel Face Recognition System by the Combination of Multiple Feature Descriptors

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Abstract: Face recognition system best suits several security based applications such as access control system and identity verification system. A robust system to recognise human faces, which relies upon features, is proposed in this work. Initially, the reference face is created and the features are extracted from the reference face by feature descriptors such as Local Binary Pattern (LBP), Local Vector Pattern (LVP) and Gabor Local Vector Pattern (GLVP). The extracted features are combined together and are clustered by employing cuckoo search algorithm. Finally in the testing phase, the face is recognised by Extreme Learning Machine (ELM), which differentiates faces by considering facial features. The public database 'Faces 95' is exploited for analysing the performance of the system. The proposed work is analysed for its performance and evaluated against existing algorithms such as Principal Component Analysis (PCA), Canonical Correlation Analysis (CCA), combination of CCA and k Nearest Neighbour (k NN) and combination of CCA and Support Vector Machine (SVM) and experimental results are satisfactory in terms of accuracy, misclassification rate, sensitivity and specificity.

Keywords: Face recognition system, LBP, LVP, GLVP, ELM.

Received January 8, 2016; accepted November 17, 2016

1. Introduction

Of late, face recognition has gained substantial spotlight, due to the strong security concern. Face recognition is a boon to security systems that are meant for access control and identity authentication systems. Face Recognition (FR) is a separate research area, which focuses on identification of faces available in the database. Unlike humans, machines can recognise faces with proper and effective training. The training process is the most significant phase of any FR system. A system can be able to recognise faces effectively, when it is trained with appropriate features being extracted from the face images.

A good face recognition system must withstand the challenging attributes such as noise, image scaling and illumination [1, 30]. There are many reasons for the presence of noise in images. Noise may arise at different processes such as image acquisition and image transmission. Image scaling is the event of resizing an image. Illumination refers to several lighting conditions. Thus, a face recognition system must work effectively against image noise, scaling and illumination [14].

Normally, there are three fundamental steps of recognising faces and they are face representation, detection and identification. Face representation can be done by exploiting templates, features and appearance of an image. Face detection is achieved by taking the location and size of image or image attributes into account. Finally, the face is recognized by matching

the query face image with the available database of faces.

The FR systems can be classified into two types with respect to features. They are FR systems based on global features and local features based face recognition system. Certain popularly known global feature based FR systems are Eigenface [21] and Fisherface [5]. The main drawback of these systems is the inability to deal with local distortions. Local feature descriptors serve its purpose effectively and some of the best samples are gabor features [6, 11] and Local Binary Pattern (LBP) [4].

This paper proposes a FR system, which is based on reference face creation and feature extraction. The local texture descriptors such as LBP, Local Vector Pattern (LVP) and Gabor Local Vector Pattern (GLVP) extract the facial features. The features extracted by the feature descriptors are grouped by the cuckoo search algorithm. Finally, Extreme Learning Machine (ELM) is exploited as classifier for recognising faces.

The major building blocks of the paper are its reference face formation, feature extraction by several feature descriptors and clustering. The reference face formation is to withstand the illumination changes and it represents the common face for all faces. This reference face formation makes further processing easier and conserves time. Features are then extracted from the reference face by the application of LBP, LVP and GLVP. LBP is incorporated, owing to its resistance against monotonic illumination changes. LVP is employed, as it works over varied distance and

directions along the pixels. This improves the discrimination ability of the feature descriptor. Finally, GLVP is incorporated by the initial application of gabor filter, which is then followed by the LVP application. Gabor filter is normally employed for effective edge detection and texture feature extraction. Thus, this work proposes to club all these feature descriptors together, in order to arrive at an effective face recognition system.

The features extracted from the images by LBP, LVP and GLVP are combined together. Clustering is the next phase in which the similar feature sets are grouped together and this process simplifies the face recognition task. This step contributes its best to the testing process. The feature set of a single cluster consists of similar set of features. Thus, the test image feature is matched with the most similar cluster initially, which is then followed by the classification process. This results in time conservation and enhanced face recognition capability.

The performance of the system is analysed with respect to accuracy, misclassification, sensitivity and specificity rate and the outcome is observed to be satisfactory. The competence of the proposed work is evaluated against Principal Component Analysis (PCA), Canonical Correlation Analysis (CCA), combination of CCA and k-Nearest Neighbour (KNN), combination of CCA and Support Vector Machine (SVM).

This remainder of this article is organised as follows. The summary of the existing works relevant to the FR systems is given in section 2. The proposed feature based FR system is introduced in section 3. The competence of the proposed work is analysed in section 4. At last, section 5 is loaded with the concluding remarks.

2. Background and Preliminaries

This section reviews the relevant literature work on the FR systems and several different feature descriptors.

2.1. Face Recognition System

The work proposed in [3] utilizes LBP for recognising faces and the classifier being employed is nearest neighbour classifier, which is based on chi square dissimilarity measure. The outcome of this work is evaluated with FERET database and the experimental results of this work outperform PCA, Elastic Bunch Graph Matching (EBGM), Bayesian classifier. The authors then analysed the obtained results for determining the efficiency of LBP and the power of LBP is proved in [2]. In [21], the age of the human is determined by examining the face. This work involves recognizing the face, followed by which the texture and shape features are extracted and Artificial Neural Network (ANN) is utilized for the purpose of classification.

In [17], Local Gabor Binary Pattern (LGBP) is incorporated along with the ensemble of piecewise Linear Discriminant Analysis (LDA). This results in reduced dimension of features and improved performance. The authors of [25] claimed that Gabor phases are quite beneficial to face recognition systems. The gabor phases are encoded by the LBP operator and the local histograms are generated. The recognition rate of this work is remarkable.

LBP can be combined with other techniques for enhanced local feature description. For instance, several approaches propose to combine gabor wavelets and LBP features [7, 11, 22]. The gabor wavelets and the LBP features are complementary to each other, as LBP focuses on local appearance and the gabor wavelets extract the shape information. These two approaches can be combined in either serial or parallel fashion [18, 19, 23]. In the serial fashion, the gabor filters are applied initially which is followed by LBP [26, 27]. The parallel mode fuses both the approaches at the feature and the classification stages. In [9], the LBP and SIFT approaches are applied in a serial fashion. Thus, it is proved that this way of combining different techniques yield better local feature description.

Motivated by these existing works, this paper strives to provide a robust face recognition system by combining different feature descriptors. The positive direction of the proposed work is explained in the forthcoming sections. The main theme of this work is to arrive at an efficient face recognition system under different illumination condition by the combination of different feature descriptors such as LBP, LVP and GLVP. The experimental outcome of the suggested algorithm is satisfactory. The preliminaries of the proposed work are presented in the following subsections.

2.2. Local Binary Pattern

LBP is proved to be the best texture descriptors and was proposed by Ojala *et al.* [16]. LBP is claimed to be effective because of its resilience to different illumination and its least computational overhead. LBP is widely employed in several face and expression recognition [3, 4, 13, 15, 16, 17, 29]. In LBP, the properties of the surrounding pixels of every pixel are taken into account, which makes it possible to produce good results. An image is composed of several regions and binary descriptive pattern is produced. Finally, a histogram is generated such that the information about the image is distributed, based on the intensity.

$$lbp(b) = \sum_{i=0}^{b-1} v(x) \quad (1)$$

$$v(x) = \begin{cases} 1, & b_p \geq b_c \\ 0, & b_c \geq b_p \end{cases} \quad (2)$$

Where b is the entire count of blocks in an image, b_p is the surrounding pixel's value and b_c is the centre pixel's value.

For instance, consider an image and segment it by 8×8 blocks. LBP considers every pixel and takes its eight surrounding pixels into account. The centre pixel value is considered as the threshold. In case, if the surrounding pixels' value is lesser than the threshold, then set the value of the pixel as 0 else set 1. This step is followed by the computation of histogram and finally, the histograms of all blocks are normalised. Thus, the feature vector of an image is made possible. The major drawback of this descriptor is its longer feature vector.

The most impressive feature of LBP is its representation of local structure of the image, which is obtained by comparing each pixel with the neighbour pixels. LBP involves lesser degree of computation complexity and the tolerance level with respect to monotonic illumination changes is remarkably high [25]. This original LBP operator can be enhanced in terms of discriminating ability, robustness, neighbourhood selection, 3D data extension and finally combining LBP with other approaches.

2.3. Local Vector Pattern

Local vector pattern is the pattern in which the surrounding twenty five pixels are taken into account. LVP collects more features with respect to different angles such as 0, 45, 90, 135 degrees, which is shown in Figure 1. This is accomplished by splitting the image into 7×7 blocks. The entire column and row of the centre pixel are considered.

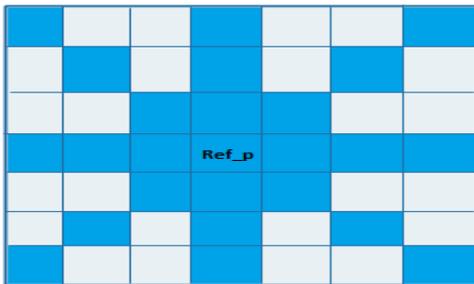


Figure 1. Local vector pattern.

Then, the immediate surrounding pixels of the centre pixel and the pixels that are of distance 2 from the centre pixel are considered. Finally, the left and right corner pixels are taken into consideration. Thus, LVP concentrates on twenty five pixels out of forty nine pixels in a 7×7 image block [9, 24]. LVP is an efficient local pattern descriptor, which works on the basis of the vector of each pixel. The vector is computed by taking the corresponding and its neighbour pixels with varying distance and directions.

$$lvp_{a,d}(Ref_p) = \{lvp_{a,d} | a = 0^\circ, 45^\circ, 90^\circ, 135^\circ\} \quad (3)$$

$$lvp_{a,d}(Ref_p) = \{lvp_{a,d} | d = 1, 2, 3\} \quad (4)$$

Where a is the angle and d is the distance connecting the reference pixel with the neighbour pixel. Both the Equations (3) and (4) indicate the important operations of LVP. The equation 3 indicates different angles and Equation (4) denotes different distances in terms of pixels.

2.4. Gabor Local Vector Pattern

Gabor local vector pattern is another feature descriptor, which follows the principle of applying gabor filter and then LVP is applied. Initially, the gabor filter of size 7×7 is applied over an image and then LVP, as discussed in section 2.3 is applied. Gabor filter is normally employed for effective edge detection and texture feature extraction. Gabor filters are very popular in pattern recognition and is clubbed with LVP for extracting better information about the pixels. Gabor filters are generated by Equation (7)

$$GLVP_{Ref_p} = gf \cup lvp \quad (5)$$

$$gf = f(a, b, \omega, \theta, \sigma_a, \sigma_b) \quad (6)$$

$$f(a, b, \omega, \theta, \sigma_a, \sigma_b) = \frac{1}{2\pi\sigma_a\sigma_b} \exp\left[-\frac{1}{2}\left(\frac{a}{\sigma_a}\right)^2 + \left(\frac{b}{\sigma_b}\right)^2 + k\omega(a\cos\theta + b\sin\theta)\right] \quad (7)$$

$$lvp = lvp_{a,d}(Ref_p) \quad (8)$$

Where ω is the frequency, θ is the orientation, (a, b) is the pixel coordinates, σ is the spatial width. This generated gabor filter is imposed over an image followed by the exploitation of LVP.

GLVP is an extension of LVP with gabor features. GLVP shows stable outcome for recognition of faces. Thus, an enhanced face recognition system under different illumination condition is proposed by clubbing the three novel feature descriptors. Thus, the discrimination ability of the proposed work is relatively high.

3. Proposed Approach

In this work, each face present in the experimental database can be observed with various illumination conditions. Initially, a root face is computed by taking the same face with different illumination conditions. The proposed approach relies on features and thus three different pattern descriptors such as LBP, LVP and GLVP are employed for feature extraction. It is advised to combine several number of feature descriptors, so as to arrive at accurate results [14].

3.1. Overview of the Proposed Approach

The proposed approach recognises face by means of features, being extracted by LBP, LVP and GLVP. The major phases involved in this work are reference face formation, feature extraction, feature grouping and classification. Reference face formation is necessary,

because this work handles several photographs of a single face under different light settings.

This reference face computes the average of all blocks of images with the same face. The features are then extracted from the images by several feature descriptors such as LBP, LVP and GLVP. This step is followed by the grouping of similar features together, which is achieved by the cuckoo search algorithm. Finally, the database of images is classified by taking the query image into account.

Thus, the entire work is organized into training and testing phases. Training phase is meant for the system to gain knowledge about the faces by means of feature extraction. All the extracted features are clustered together with respect to the relevancy or similarity and the outcomes are stored for future classification purposes.

In the testing phase, a query image is passed into the system. Features of the query image are pulled out by LBP, LVP and GLVP. The extracted features are concatenated and are compared with the trained feature vectors. Finally, ELM recognises the query face from the pool of face images. The steps involved in the proposed work are presented below and the complete flow of the system is depicted in Figure 2.

1. Training

- 1.1 Load database
- 1.2 Form reference face
- 1.3 Extract features with LBP, LVP and GLVP
- 1.4 Combine the extracted features
- 1.5 Calculate cosine similarity between feature vectors
- 1.6 Apply cuckoo search algorithm to group related features

2. Testing

- 2.1 Load input image
- 2.2 Extract features with LBP, LVP and GLVP
- 2.3 Combine the extracted features
- 2.4 Compare it with the trained feature set.
- 2.5 Recognise the face of the input image by ELM.

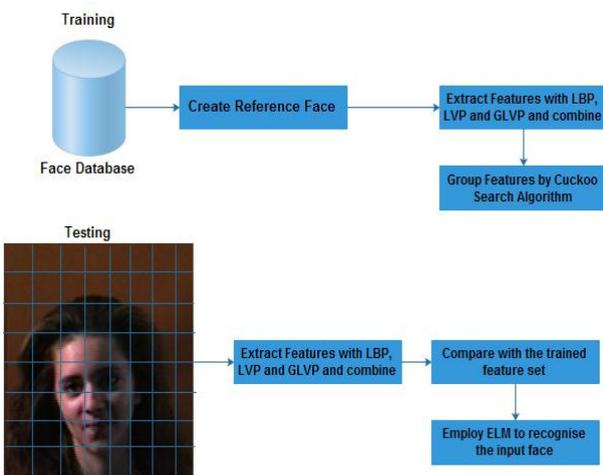


Figure 2. Overall flow of the system.

In the training phase, the database is loaded and the reference face is formed. The experimental database

contains same face under different illuminating environment. Thus, this work proposes to form a base face, as a representative for all faces. The reference face is further processed by the application of LBP, LVP and GLVP. The application of GLVP follows serial fashion, which means that the Gabor filter is applied initially and is followed by the LVP. The so extracted features are combined together and cosine similarity is employed to determine the similarity of the feature vector. Finally, the cuckoo search algorithm is applied to cluster related feature sets. The clustered feature set is saved in the database for further processing.

In the testing phase, the user is prompted to load the input image. The input image is then processed through feature extraction, which is accomplished by LBP, LVP and GLVP. The extracted features are combined together and the resultant feature set is compared with the already stored clustered feature set, with respect to the range. As the clustering process is already done, the images with similar feature set alone are taken into account. This improves the accuracy of the work. The classification process is accomplished by ELM, which selects the appropriate match for the input image.

3.2. Reference Face Formation

The first step of the proposed work is to create a reference face for all images. This work considers the same face images under different illuminating conditions. For instance, there are ten faces of the same person under various illuminating conditions. Thus, the basic face for all the ten faces is created and is named as reference face.



Figure 3. 100 faces of 10 persons with different illumination.



Figure 4. Reference faces.

The reference face is formed by calculating the mean of all ten faces and the resultant face is the

reference face. The faces with different lighting conditions and the resultant reference face are presented in Figures 3 and 4 respectively.

Let image ‘A, B,..J’ are faces that are divided into several blocks and each block is of size 8×8. Let $A_1, A_2.. A_{10}$ are the face images of the person A under different illumination. Let $A_{11}, A_{12}..A_{18}$ be the blocks of imageA. The reference face for ‘A, B,..J’ can be found out by calculating the mean of $\{A_{11}, A_{21}.. A_{101}\} \{A_{12}, A_{22}.. A_{102}\}$

$$\{A_{18}, A_{28}.. A_{108}\}. \tag{9}$$

$$A = A_{11} \cup A_{12} \cup A_{13} \cup \dots \cup A_{18}$$

$$R.F_A = \begin{cases} (A_{11}, A_{21}.. A_{101})/10 \\ (A_{12}, A_{22}.. A_{102})/10 \\ \vdots \\ (A_{18}, A_{28}.. A_{108})/10 \end{cases} \tag{10}$$

Similarly, the reference faces for all the images from B, ..J are computed respectively and are processed further for feature extraction.

3.3. Feature Extraction

Feature extraction is the vital step of an FR system. In this work, we strive to extract features from the face images by exploiting different feature descriptors such as LBP, LVP and GLVP. These feature descriptors are explained in sections 2.2 through 2.4. Thus, the features are extracted and then the features are grouped together. Figure 5 shows the face images, which are applied with LBP, LVP, GLVP and fusion of all the three texture descriptors.

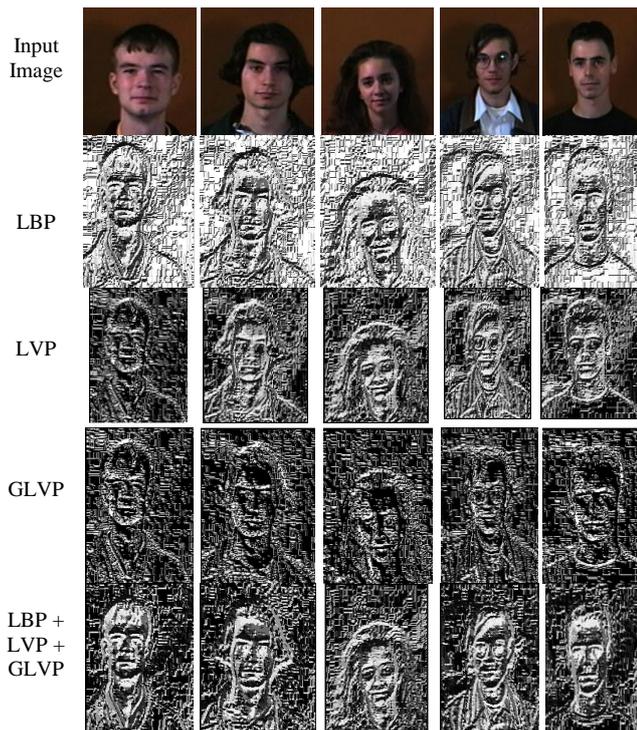


Figure 5. Impact of feature descriptors.

The above Figure shows the power of combining multiple feature descriptors. It can be observed that the individual feature descriptors do not preserve edges and the combination of LBP, LVP and GLVP can clearly distinguish between different parts of the face.

3.4. Feature Grouping

Feature grouping is the process of clustering related features together by means of cuckoo search algorithm. The correlation between the features is calculated by the cosine similarity measure. The cuckoo search algorithm is a bio-inspired algorithm that clusters the features with respect to the correlation between the features.

This similarity measure is responsible for calculating the degree of relevance between the features. The degree of cosine measure is calculated between two feature vectors and is accomplished by Equation (12).

$$Sim_c(ft_a, ft_b) = \cos(ft_a, ft_b) \tag{11}$$

$$\cos(ft_a, ft_b) = \frac{\sum_{i=1}^n w_{ai}w_{bi}}{\sqrt{\sum_{i=1}^n w_{ai}^2 \sum_{i=1}^n w_{bi}^2}}, a \tag{12}$$

The outcome of Equation (12) ranges from 0 to 1. The correlation value is then fed into the cuckoo search algorithm, such that the relevant or related features are grouped together. The outline of the concept of cuckoo search algorithm is that each cuckoo lays an egg and places it in an arbitrarily selected nest. The best nest that contains eggs with high quality is considered for the future generations. This cuckoo search algorithm is utilized and the input to this algorithm is the correlation coefficient and the feature vector. The cuckoo search algorithm chooses the best room for all the features, and thus the relevant features are grouped together.

3.5. Classification

This part becomes active only in the testing phase. In this stage, ELM recognises the face by matching the input image with the database of face images. The ELM is employed as the face recognising entity.

Initially, ELM is trained with the feature set of face database. In the testing phase, ELM recognises the face with respect to the correlation of feature. The classification is achieved by difference of values between the feature set and calculated by the following Equation.

$$D = (\sum_{i=1}^n |x_i - y_i|^s) \tag{13}$$

Where x_i and y_i are the feature sets of x, y faces. Based on this difference, the faces are recognised by matching it with the existing feature set. This system proves its efficiency in recognising faces and the forthcoming section analyses the performance of the proposed work. This work tends to club several feature descriptors together, so as to acquire as many features

as possible. A face can effectively be recognized with more number of features. In order to improve the accuracy rate, this paper proposes to cluster the related features together and classification is achieved by the utilization of ELM.

4. Performance Analysis

This section intends to analyse the performance of the proposed approach by comparing it with analogous techniques and the experimental results are presented. This work utilizes the Faces 95 database, which possesses 100 different faces, under various illumination [8]. Each face has 10 different images on different illumination. The comparison is done in three ways. Initially, the performance of the work is carried out with and without reference face creation and the results are shown in Figure 6. Secondly, we employ LBP, LVP, GLVP individually for the sake of feature extraction and is compared with the combination of LBP, LVP and GLVP as shown in Figure 7. Finally, the performance of the work is tested with respect to classifier. In this case, the performance of ELM is tested against k-NN and SVM, which is shown in Figure 8. The experimental results prove the efficacy of the proposed work. The experimental results are presented in Table 1.

Table 1. Performance analysis.

Techniques	Accuracy	Sensitivity	Specificity
Without Reference face	96.2	95.4	87.2
With Reference face	99.9	100	90
Feature Descriptors			
LBP	86	84	85
LVP	88	83	84
GLVP	93	90	88
LBP+LVP+GLVP	99	98	96
Classifier			
k-NN	85	86	84
SVM	92	89	92
ELM	98.9	98.1	98.5

- **Accuracy:** Accuracy is the measure that determines the effectiveness of the system by means of accurate recognition of faces. Accuracy rate is measured by the correctly recognised faces to the total number of attempts made for recognising faces. It is calculated by

$$acc = \frac{C.R.F}{Total\ number\ of\ attempts} \times 100 \tag{14}$$

Where C.R.F is the correctly recognised faces.

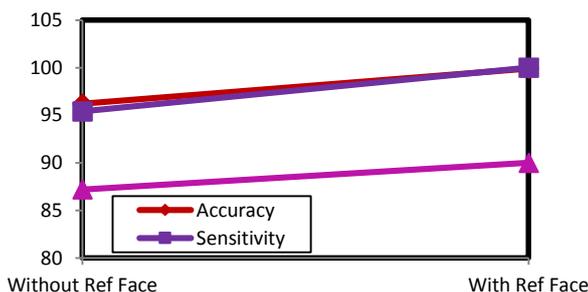


Figure 6. Performance analysis w.r.t reference face.

- **Sensitivity rate:** Sensitivity rate can also be called as true positive rate, which makes sense that correct identification or recognition of faces. It is calculated by

$$sensitivity = \frac{t.p}{t.p+t.n} \tag{15}$$

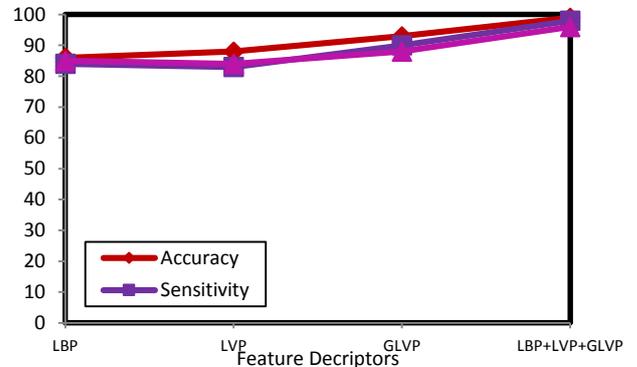


Figure 7. Analysis w.r.t feature descriptors.

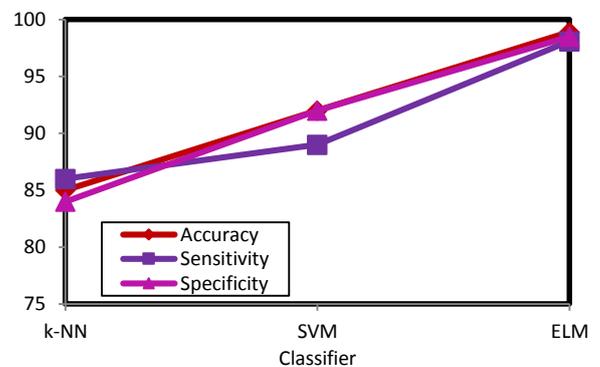


Figure 8. Analysis w.r.t classifier.

- **Specificity rate analysis:** Specificity rate can also be called as true negative rate, such that a face recognition system should reject the faces that are not similar to the query image.

$$specificity = \frac{t.n}{t.n+f.p} \tag{16}$$

Thus, the face recognition system is proved to be effective with the evidence of higher sensitivity and specificity rate.

From the experimental results, it can be concluded that the proposed work proves itself by showing maximum accuracy, sensitivity and specificity rates. The performance of the work is analysed in different scenarios such as with and without reference face, by varying feature descriptors and classifiers, so as to justify the result.

The results of the code which excludes the reference face appear computationally fast, however the accuracy rate is minimal. The objective of any face recognition system is to have maximum accuracy rate and is satisfied by this work. The results with respect to feature descriptors show the power of combination of multiple feature descriptors. Finally, the analysis with respect to the classifier proves the efficiency of ELM against k-NN and SVM.

Thus the statement, “The combination of several number of feature descriptors lead to accurate results” is justified. Besides the process of feature extraction, the reference face formation is an added credit to this work. The reference face formation simplifies the succeeding processes. The process of clustering during the training process conserves more time, while testing an input image. Thus, this work lands at improved accuracy, specificity, sensitivity, reduced misclassification rate and time consumption.

5. Conclusions

This paper presents a novel face recognition system, which relies on reference face creation, texture feature extraction, clustering and classification. The reference face creation is a new idea, which can fight against the varying illumination condition. Additionally, this work proposes to combine three different feature descriptors such as LBP, LVP and GLVP for extracting features. This step along with the reference face creation improves the accuracy rate. The extracted features are then clustered together by cuckoo search algorithm, such that the testing process would consume lesser period of time. Finally, the classification is done by ELM classifier. In future, this work plans to reduce the time complexity.

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