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Enhancing Face Recognition in Surveillance Systems Using Local Binary Pattern and (PCA) Based Feature Selection

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Abstract
Face recognition is a critical component of biometric systems utilized for surveillance to identify criminals, suspected terrorists, and missing children. This paper presents the application of the Local Binary Pattern (LBP) method for feature extraction in face recognition, recognized for its robustness and effectiveness. The primary contributions of this research include the use of LBP to extract key facial features and the implementation of Principal Component Analysis (PCA) to refine these features by eliminating irrelevant data, thereby enhancing classification accuracy. Given the high dimensionality of facial data, selecting significant features is crucial for effective recognition. For classification, two algorithms Support Vector Machine and Linear Discriminate (LD) were employed to analyze the feature vectors derived from the LBP method. Experimental validation was performed on the standard benchmark dataset from the Olivetti Research Laboratory (ORL). Such accuracy shows that the proposed system is more accurate than the previous models. I have also conducted an analysis of classifier performance with all features in comparison to classifiers refined by PCA, and though full-feature classifiers outperform PCA classifiers overall, PCA classifiers reward us with time efficiency advantages. It finds the durability and effectiveness of the proposed face recognition system with combination of LBP and PCA features.
Keywords: Face Recognition, Local Binary Pattern, Principal Component Analysis, Feature Extraction, Biometric Surveillance

1- Introduction

For the applications that are supposed to provide the service only to the authenticated users, a strong identity management system is critical. Having such systems is critical to very sensitive areas of life, including sharing access to computer resources, entering a nuclear facility, online banking transactions, or boarding a commercial flight. The emergence and adoption of electronic services, including online banking and the proliferation of decentralized customer service points (following the credit card model), have also highlighted the need for advanced and secure identity verification methods. [1] Historically, verification of identity was based on systems that required knowledge of a secret (passwords) or the use of a token (ID cards). Although these systems have long been used as the bedrock to inform identity, they can have inherent weaknesses that undermine security. Consider passwords: While easy to remember, they are also relatively easy to get a hold of or guess, especially if they are a simple password or a commonly used password. In contrast, token based methods like ID cards are susceptible to being lost, forged, and stolen, which can compromise security by allowing unauthorized access. [2], [3] The challenges posed by the traditional systems present opportunities for biometrics to take the lead with its more organic and secure method of recognizing individuals by their biological characteristics.

Traditional methods typically utilize tokens (passwords, ID cards) that are easily replicated, shared, lost or forgotten and can therefore be vulnerable to exploitation. Biometrics provides not only enhanced security but also greater user convenience by allowing the easier, but safe, authentication process compared to other methods. The beneficial characteristics of biometric systems in comparison to traditional security measures are negative recognition and non-repudiation. [4] Negative recognition is a feature that allows the identity management system to determine whether the individual is already in the system, known by some other name, even if that individual denies the connection. This feature is ideal for countering fraud in grant distribution systems, service systems or really any system where someone might attempt to use multiple identities to collect funds in an ongoing fraudulent scheme. [5] The biometric(physiological) system provides non-repudiation because once an individual has accessed the service, he/she can not deny for its involvement as it needs the physical presence of that individual to get authenticated. Face Recognition (FR) is one of the popular biometrics techniques since it is non-intrusive and can be used in both controlled (e.g., frontal image) and uncontrolled (e.g., social media) environments. Face-recognition systems will work across a set of scenarios ranging from static set-ups (similar to mug shots) to variable and unconstrained environments such as those we find in metros or airports. These systems can be divided to feature-based and appearance-based approaches. [6] Feature-based methods analyze the geometry of features, like the eyes, nose, and mouth, as well as the relative positioning of those features, while appearance-based methods analyze the face in its entirety. However, current face result examples are not without their challenges, and there are still many areas for improvement to make them more reliable and accurate. Such difficulties involve controlled illumination, specific backgrounds, and restricted exposure angles of the face. Deep learning improvements recently have been employed to enhance face detection and face recognition in order to mitigate these problems.

2- Proposed System

This study designs a face recognition system depicted in Figure 1. The system was tested using the ORL database. Features required for classification were extracted using the Local Binary Pattern (LBP) approach. The principal component analysis (PCA) method was subsequently applied in order to fine-tune these features, by selecting the best features among the total feature vectors generated in the extraction phase. The filtered attributes require to be passed through Support Vector Machine (SVM) and Linear Discriminate (LD).[11] They found that the proposed system increased the accuracy and the efficiency of the classification. The comparative results using the full set of features and the subset of those selected through a PCA methodology are included to show the functionality of the proposed system as well. The next subsections present a comprehensive breakdown of each stage in the system. [12]

2-1 Dataset

The database from Olivetti Research Laboratory is a dataset specifically designed for face recognition research. It comprises 400 grayscale images of faces, collected in 1992 from 40 individuals. Each image within this database has dimensions of 92x112 pixels. For the purposes of this experiment, 8 images from each of the 30 selected individuals were used. Figure 2 showcases all the faces included in the database.[13]

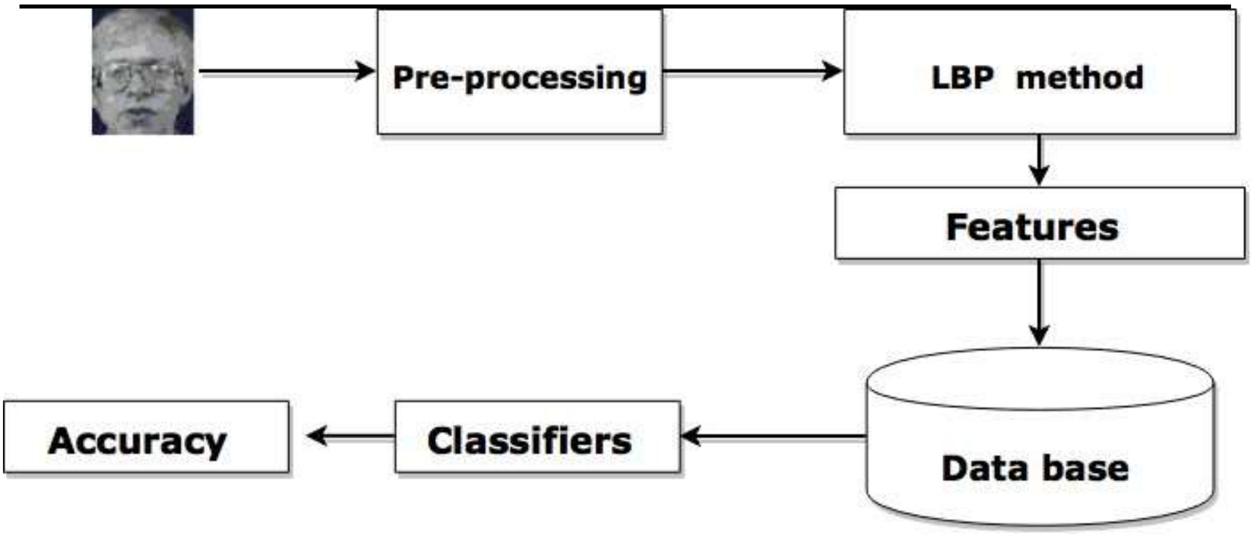

Figure 1. Proposed system

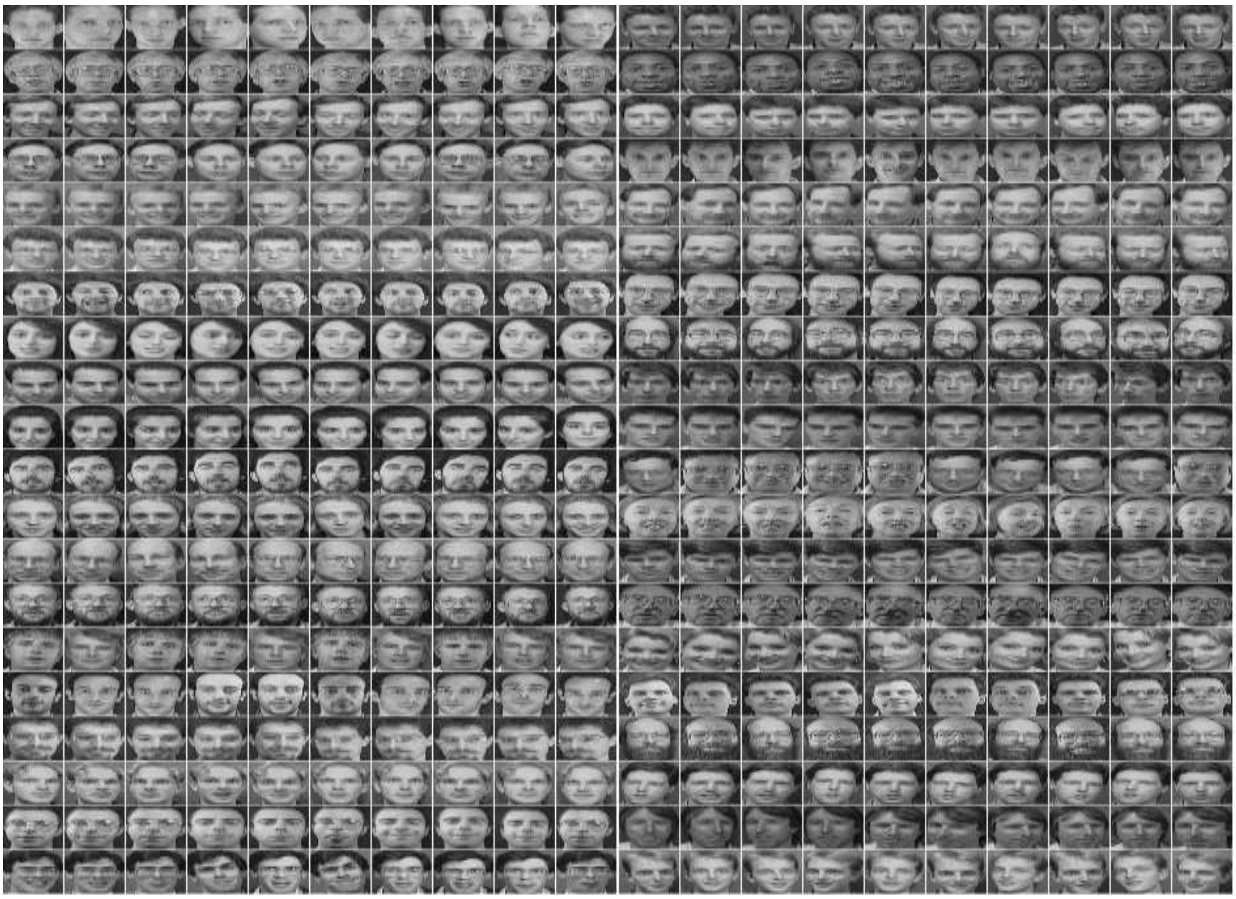

Figure 2. ORL database

2-2 **Pre-processing**

In the preprocessing steps, the Local Binary Pattern (LBP) feature extraction method was utilized. Here is a detailed explanation of this method:[14]

A- Local Binary Pattern

The Local Binary Pattern is an important Method for extracting key features from facial images. Introduced in 1996 by Ojala et al. [5], LBP is used to capture the texture and shape of an image by dividing it into several small regions, from which features are extracted.[15], [16] Figure 3 illustrates a central pixel surrounded by its 8 neighbors. If the value of the central pixel is lower than that of a neighbor, that neighbor's value in the pattern becomes one; otherwise, it remains zero. Through the application of the LBP method, 120 distinct features are extracted. These features are subsequently utilized for classification in the development of face recognition systems.[17]

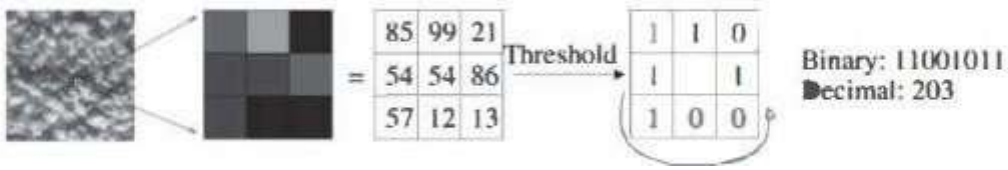

Figure 3. The basic local binary pattern method

B. Principal Component Analysis

Principal Component Analysis is a highly important method for the face Recognition. Numerous studies have utilized the PCA approach to reduce the dimensionality of facial features. When features are extracted from a face, they often include a large number of redundant or irrelevant components. [18]To address this, PCA transforms the features into a new subset of ordered variables. This transformation ensures that the first few features capture most of the variation present in the entire dataset. PCA employs least square decomposition to perform a linear projection of high dimensional, multivariate data onto a lower dimensional subspace. The primary goal of PCA is to identify orthogonal directions that exhibit the strongest variability in the data. In the present system, PCA has been applied for dimensionality reduction, reducing the number of features from 120 to 64.[19] These selected features retain the most significant and relevant information compared to the discarded ones. Given a set of d dimensional independent data vectors X_i where i ∈ 1,⋯ ,n, PCA executes an orthogonal projection to achieve this transformation effectively.

$$Y_t = A^T(x_t - \mu) \quad 1$$

The Transmuted data is represented as y where μ denotes the pattern mean of the observed data. The sample covariance matrix is calculated as follows:

$$S = \frac{1}{n} \sum i = 1^n \, (x_i - \mu)(x_i - \mu)^T \quad 2$$

The reconstruction error is computed by E_r:

$$E_r = \|x - \mu - y_{A_g}\|^2 \quad 3$$

2-3 **Classification Algorithms**

Two classification methods, Support Vector Machine (SVM) and Linear Discriminant Analysis (LDA), have been implemented for the purpose of recognition. A detailed description of these classifiers is provided.[20], [21]

3. Experimental Setup

The proposed system is developed in Matlab R2015 in a system of Windows 10 professional 64-bit with Intel Core i7 processor and 16 Giga Byte of RAM. Table 1 Displays the presentation indicators of the suggested system which performs better compared to existing systems. [22] To improve the system even more, it was decided to include the PCA (Principal Component Analysis) method for dimensionality reduction. After applying PCA, a total of 64 high ranked features from the original feature set were selected. The selected features were then utilized to perform classification using the Support Vector Machine (SVM) as well as the Linear Discriminant Analysis (LDA) algorithm. [23] SVM using the combined feature set achieved classification accuracy of 98.13% and the SVM using PCA reduced set achieved 97.44% on the performance metrics. ACFILD gives an accuracy of (99.10%) for LDA with all features, whereas PCA-reduced features give 97.98%. 24 This relative performance of the models shows a clear trade off: although the reduced feature set brings down accuracy slightly, it is much cheaper computationally. [25] State that this property results in a more efficient performance for both SVM and LDA classifiers by using a PCA-reduced set of attributes with not too much accuracy degradation. [26]

Models	Features vector	Times in Seconds	Accuracy
Liner Discriminant (LD)	All The Features	165.13	98.10 %
	Principal Component	31.17	98.98 %
Support Vector Machine (SVM)	All The Features	197.68	97.13 %
	With Principal Component	68.55	96.44 %

Table 1. Outcomes of classifiers for facial recognition

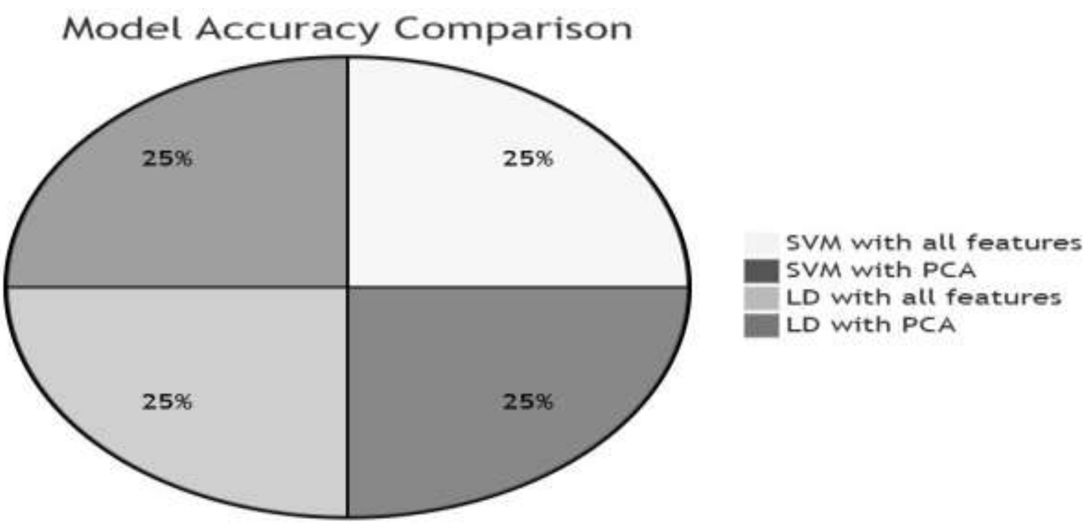

Figure 3. Accuracy of proposed system Performance

The performance of the proposed system is shown in Fig. 3, which compares the results of the SVM and LD classifiers, using the full set of features in addition to the set at the output of PCA.[27] [28] Hence, the designed system accurately classifies faces.

4. Conclusion

This paper is aimed to develop a face recognition system. To achieve this, the Local Binary Pattern method is to be used to compute prominent parameters from faces. The LBP technique has shown its impact in superior representation of facial features. In this approach, we state that the use of LBP can help us to achieve a higher recognition rate since it is proven that it is capable of capturing the details of the face accurately [17]. Face data has a very high dimension and therefore is one of the main reasons why we get an improper recognition. In order to solve this problem, we have adopted PCA method to reduce the dimension, eliminating unnecessary and irrelevant attributes to improve classification performance. In particular, the PCA has been applied to retain the top 64 features from the above total features set. The proposed system utilizes systematically selected diverse features for face recognition. Support Vector Machine (SVM) and Linear Discriminant Analysis (LD) algorithms have been used for the classification of these features. The proposed system's empirical results are comprehensively compared. As for the whole set, the system reached 99.10% and 98.13% accuracy for LD and SVM, while LD and SVM with the reduced set achieved 97.988% and 97.44% accuracy. The results reported here confirm that classifiers from PCA, while producing very good performance, provided a better time for construction of the system. In future working researchers will work on new feature extraction techniques to make the face recognition system even more robust and accurate.

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