Evaluation of the most appropriate Kernel Function for the Purpose of Feature Extraction in Face Recognition in video surveillance systems

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Abstract - It is believed that Kernel Principal Component Analysis (KPCA) merits the performance of Principal Component Analysis big time. KPCA is the nonlinear extend of Principal Component Analysis (PCA) meaning that in KPCA the input data is first mapped by using nonlinear Kernel and then PCA is performed on the mapped data. Kernel function has been categorized into four different categories such as Linear, Polynomial, Gaussian, and Sigmoid. In this work the performance of the mentioned methods on Surveillance Camera Faces database is observed to determine the significance of Polynomial KPCA compared to other types of that in terms of video surveillance recognition.

Keywords: Face recognition, Kernel Principal Component Analysis (KPCA), video surveillance systems, Pattern recognition, Biometrics.

1 INTRODUCTION

Security has always been one of the most important matters. Identification and verification are two challenging areas of biometrics[1]. Verification, however, could be having fewer difficulties to overcome in comparison to identification as it is a cooperative recognition method meaning that the person to be verified is totally willing to be recognized. In identification the target does not have the tendency to be known; for instance, illegal immigrants who are on the run, or criminals. In this case, there are some more problems to overcome which make the system more demanding. The mentioned problems have made researchers think of even using surveillance video cameras [2] to recognize people when it is necessary as in today’s world, surveillance cameras can be found everywhere.

Having the idea of using video surveillance systems, some more difficulties are added to be dealt with such as uncontrolled environment, uncontrolled illumination, using different cameras with different qualities, different resolutions, and also different distance to capture the test photos. Surveillance Camera Faces database is a face database to which all of the mentioned difficulties have been added as 5 different cameras with different qualities and resolutions were used to take the photos from 3 different distances, which makes the database similar to real world. Principal Component Analysis (PCA)[3][4] is a powerful method to extract the features from the data to ease the computational part and data analysis and enhance the reliability of the results in case of face recognition. While PCA is a linear method, KPCA[5] nonlinear meaning that the data first is nonlinearly mapped to a new feature space called F and then linear PCA[6] is implemented on the mapped data. The fact that the performance of KPCA [7] is more appropriate than PCA in many cases has been proven, which is why we tend to implement it on SCface database to signify the importance of Polynomial KPCA compared to PCA and other types of KPCA[8].

The remaining of this paper is organized as follows:

In Section 2, Kernel Principal Component Analysis (KPCA) is introduced briefly. In Section 3, Surveillance Camera Face database is explained. In Section 4, experimental results on SCface database are given and discussed. Finally, Section 5 concludes the paper.

2 KERNEL PRINCIPAL COMPONENT ANALYSIS (KPCA)

Improving the performance of Principal Component Analysis (PCA), Kernel PCA was proposed. Kernel PCA is exactly the same as PCA except for the fact that before implementing PCA on dataset, all data are mapped nonlinearly in another feature space called F using a nonlinear mapping Φ[9],[3]. After centering F, \( \Sigma_{i=1}^{M} \Phi(X_i) = 0 \), number of input data is \( M \), and then covariance matrix of F is obtained using Eq.(1)

\[
C = \frac{1}{M} \Sigma_{i=1}^{M} \Phi(X_i)\Phi(X_i)^T
\]  

(1)
eigenvalue equation: \( \lambda v = Cv \) is then solved using \( \lambda \geq 0 \) (eigenvalues), and \( v \in \mathcal{F} \) (eigenvectors).

Because \( Cv = (1/M) \sum_{i=1}^{M}(\Phi(X_i).v)\Phi(X_i) \), solutions for \( v \) where \( \lambda \neq 0 \) lie in span of \( (\Phi(X_1)\ldots \Phi(X_M)) \), all of the coefficients \( a_i (i = 1, \ldots, M) \) are achieved in a way that:

\[
V = \sum_{i=1}^{M} a_i \Phi(X_i) (2)
\]

Then we have

\[
\lambda(\Phi(X_i),V) = (\Phi(X_i).Cv) \text{ for all } i = 1, \ldots, M (3)
\]

Getting \( M \times M \) matrix \( K_{ij} = k(X_i,X_j) = (\Phi(X_i).\Phi(X_j)) \) causes the problem of eigenvalue.

The solution of the mentioned problem is

\[
M\lambda\alpha = K\alpha (4)
\]

3 SURVEILLANCE CAMERA FACE DATABASE

Many available face databases for researchers are mainly captured under controlled pose and illumination conditions using the same cameras with the same quality and resolution and constant distance. Moreover, it is mainly believed that using high quality cameras results in more confident contributions. In Surveillance Camera Face database, however, it is totally different; in this database, the purpose is to mimic the real world condition. As the qualities of cameras are different in real world, and the conditions such as illumination, pose, distance, and resolutions of cameras differ from each other too, all of the mentioned factors have been taken in account in this database. In SFCface database, 5 different cameras with different resolutions and qualities were used. Furthermore, the images were taken from three different distances. As the numbers of subjects are 130 and 15 images were taken from each subject during day (not at night), the likelihood of recognition by coincidence is very low. In Figure 1 a subset of original and cropped images of SFCfaces are shown. As it is clear from Figure 1 (b), there is a big discrepancy between the images after being cropped and normalized; it is because nothing but the fact that using different cameras with different features and distances to capture the images makes this database very demanding.

4 RESULTS AND DISCUSSION ON SCFACE DATABASE

In this section, the experiments on SFCface database are explained and the results are given and discussed. The first thing to mention is the fact that cropping images in this database is unavoidable as there is too much space of background and unnecessary information in the images which needs to be omitted in order to make the results real and the accuracy higher. The proposed method for video surveillance face recognition consists of 4 steps as shown in Figure 2. First step is to crop the images and extract the face area. Second one is to normalize images and resize them to make them as small as possible because the smaller the images are the faster the system is; based on the experiments, the smallest size which is optimum for using KPCA is 10x10. After normalizing the images, different types of KPCA is performed to extract the features and finally the accuracy is calculated using Euclidian distance. Four different implementations are conducted on the database using three different types of Kernel Principal Component Analysis (KPCA). In the first implementation, shown in Figure 2 (a), just three images from one camera are used to train and the remaining 12 images from the other four cameras are used to test. In Figure 2 (b), the results of using 2 cameras for train (6 images) and 3 cameras for test (9 images) are shown. In Figure 2 (c), and (d) the results of using 9 and 12 images to train are shown respectively. As it can be observed from the results, using more images to train
results in higher accuracy as the accuracy of over 95% is achieved using 4 cameras to train.

![Flowchart of the used method](image)

Fig. 2: Flowchart of the used method

The following results indicated in Figure 3 (a), (b), (c), and (d) relieve that polynomial Kernel Principal Component Analysis is the most appropriate method in terms of video surveillance systems as this method achieves the highest accuracy an almost all implementations compared to other types of KPCA.

![Graphs](graph1)

(a)

![Graphs](graph2)

(b)

![Graphs](graph3)

(c)

![Graphs](graph4)

(d)

Fig. 3: Results on SCface database using (a) 3, (b) 6, (c) 9, and (d) 12 images to train

## 5 CONCLUSION

In this paper, the performance of four types of Kernel Principal Component Analysis on cropped SCface database is observed to relieve the significance of polynomial KPCA. The experimental results prove that polynomial KPCA obtains better accuracy compared to other types of Kernel Principal Component Analysis in video surveillance systems.

## 6 REFERENCES


