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RESEARCH ARTICLE

An Investigation of Face Recognition Characteristics Using PCA and ICA

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Abstract

This aims to investigate the face recognition characteristics using widely adopted statistical approaches (i.e., Principal Component Analysis (PCA) and Independent Component Analysis (ICA)). This paper focus on Eigen faces approach for implementing the face recognition and detection on the images to compare the performance of PCA and ICA. Moreover, our results are reveals that based on applied condition and performance metric, turning ICA produce better results than PCA. The managerial practices and results of the paper have presented.

Key words: face detection, recognition, PCA, ICA, image processing, embedded system

1. Introduction

In the recent years, face recognition, face reconstruction, and face matching have become a wide research area in the real world practice. In the face recognition, we naturally develop the system to recognize faces. However their multiple characteristics such as various hairstyle or faces with sunglasses on or something else due to our sophisticated brain nerves. Somehow, we expect a system to help to recognize human faces to build the foundation for dealing with plenty of categories in the problem design. Moreover, basic machines having limited features (i.e., lack necessary nerves to think/remember) like human being, so it's tough for performing as precisely in the face recognition. Our system aiming this issue, experts have established multiple computational models to transform the recognition part for computers into some mathematical models to facilitate the process and explore the essence of problem sets to make computers do the computing part more specifically.

Many studies investigated several computational models (PCA and ICA) have been investigated in the face recognition. The main goal is to extract the main features of the objects instead of taking every aspect into consideration to simplify the problem. Our focus of this paper is most important part of the object which is other words can represent the object by itself varying from others. For example time-demanding problem sets, it must to perform well within a specific short period of time. In this way, when the number of the objects increases, we could reduce the time to spend on computing, thus, to decrease the whole processing time getting the relatively precise results. In addition this paper analyzes the pros and cons of PCA and ICA through comparing the performance.

In spite the relative simplicity in the data operation, it mainly set focus on the principal distribution of the sample datasets, generally capturing the differences of all the sample images despite the external (light intensity, viewpoint) and internal (facial expression) factors that effect on the final difference. The face detection and recognition(FDR) module such as recently intelligent for car systems [22] and security surveillance systems which requires instant interaction with the external and internal environment ,as face processing is a computationally intensive task, an embedded solution would give rise to opportunities for discrete economical devices that could be applied and integrated into a vast majority of applications**.** Thus, the detection and recognition part depending both on the algorithms in software and the design of hardware.

2. LITERATURE REVIEW OF RECENT PCA WORKS

In this section, a brief review on recent methodologies and application applied with PCA will be demonstrated. The literature review consists of four parts. In the first part, we introduce Two Dimensional PCA is a better approach compared to PCA on feature extraction, and then we focus on face verification which is similar to face recognition and its core concept. Then we shift to Texture analysis using the PCA, and to extend the application of PCA on other related fields.

2.1 Face detection

In order to process the face recognition, first step is to locate the human faces in digital images or videos. Different face detection techniques have played an important role recently, including motion detection neural network based methods [8] ,motion detection, and detection based on Hausdor Distance [9].

2.2 Two Dimensional PCA for Face Recognition

As compared to PCA, it is based on 2D matrices instead of 1D vector so the image matrix does not need to be transformed into a vector prior to feature extraction [1]. Moreover, an image covariance matrix is constructed directly using the original image matrices. Also the size of the covariance matrix is fairly smaller in 2D PCA than 1D PCA. Therefore, this resulted in a more efficient performance than PCA in extraction of image features, opening the door of more and more new technique to be discovered in face recognition. [2].

2.3 Face Verification

In fact, face recognition in automation has been regarded as one the most challenging tasks in pattern recognition and artificial intelligence [3].

Face Recognition can be divided into the following 2 types:

1) Face recognition: The system is responsible for processing the input face images and identifies them based on the existing databases storing known individuals.

2) Face Verification: In this, the system confirms or rejects the identity in the line accordance with the input face image.

2.4 Texture Analysis

Among most researches and algorithms on computer vision and image processing generally assume that the retrieved images are made of uniform textures to simplify the running process .However textures in images are just more complex when dealing with tasks in real world. That's when the texture analysis comes up to facilitate the course of the image processing. The final goal in this field is about extracting textural features from images and various methods have been improving all the way to lead and establishment of the geometric, random field, fractal, and signal processing models in dealing with relevant analysis. So the major category of texture processing problems such as image segmentation, classification, and shape identification from the texture.

2.5 Comparison among mainly applied methodologies

The comparison of these methods in performance and effectiveness are also taken into consideration by experts, leading to more and more discussions on applying appropriate approaches in some specific fields to get the best result. For example, the pca and ica approaches in face recognition showed relative performance depending on the statement of the task, the ICA architecture, and for PCA the subspace distance metric [7].Another comparison with pca,ica,lda was conducted also, showing that no particular algorithm-metric combination is the optimal across all standard FERET tests and that choice of appropriate algorithm-metric combination can only be made for a specific task[11].

3. Proposed Methodology

Based on the existing works and researches we analyzed principal components analysis (PCA) and independent components analysis (ICA) these two popular methodologies which have a rigid mathematical proof and are most commonly used in multiple fields in recent years. This following section will demonstrate these two on their specific mathematical approaches /relative performance/pros and cons in depth.

3.1 Algorithm

3.1.1 PCA

The principal component analysis is defined as: a methodology to collect dataset and transform them in order to enhance the statistic features of the transformed dataset, in other words, enabling the new datasets to reveal the vitally determining factor of the previously raw dataset. In this way, we could do the classification by the transformed dataset, along with eliminating the redundancies and data compression. The following segments represent general procedure and its related operation of pca algorithms:

Let X = {x_1, x_2 ..., x_n} be a random vector with observations xi € Rd.

1. Compute the mean μ

$$\mu = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (1)$$

2. Calculate the Covariance Matrix S

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

3. Compute the Eigen values λi and eigenvectors v_i of S

$$Sv_i = \lambda_i v_i, i = 1, 2, ..., n \quad (3)$$

4. Projecting training samples into the PCA subspace.

   The eigenvectors order in descending by their Eigen value. The k principal components are the eigenvectors corresponding to the k largest Eigen values. The k principal components of the observed vector x are then given by: $y = W^T (x - \mu)$ in Eq.(4) where W = (v_1, v_2..., v_k). The reconstruction from the PCA basis is given by:

$$y = W^T(x-\mu) \quad (4)$$

5. The Eigen faces method then performs face recognition by:

$$x = Wy + \mu \quad (5)$$

Taking above steps into the consideration, we could approximately analyze the performance of the algorithms

3.1.2 FASTICA

Comparatively, the independent component analysis (ICA) is intimately related to the blind source separation (BSS) problem, where the purpose is to decompose an observed signal into a linear combination of unknown independent signals. For multichannel observed signals, suppose the observed signal (**X_i=1,2,3…,M)** is from **M** channels, each of which is composed of mixing **N** independent signal **S_i (i=1,2,3…,N)** that is **Xi =A_i1Sq+A_i2S2+…+A_in Sn (1=1,2,3…,M).**

In expression of matrix**: X = A_s, A** stands for the unknown mixing matrix and **S** stands for the unknown independent source signal. While the goal of ICA is to find out the separation matrix **W** from **Y=Wx=WAs** and **A=W-1**,where **Y** represents the estimate of base vector **S** ,So, concerning that have been demonstrate above ,the major steps of ica operation displays itself as follows:

1).Set the $X = [(x_1 - u), (x_2 - u), ..., (x_n - u)]$**,** where **u** is the mean value of the training datasets;

2).Suppose the **U** and **V** are the Eigen value and the Eigen value matrix of the covariance matrix, so we get the **W^TW = (XX^T)**- 1 **and UVU** - 1**= XX^T;**

3).Then we get the whiteness matrix: $\mathbf{Wp=V^{-1/2}\ U^T}$ in which then we can work out the whiteness of x: **V=WpX;**

4).As represents above, now we can get the formula to get $\mathbf{K} = \sum \left| \mathbf{E}\left\{\mathbf{Y}_i^4\right\} - \mathbf{3}\left(\mathbf{E}\{\mathbf{Y}_i^2\}\right)^2 \right|$**;**

5).As soon as we get the maximum $\mathbf{K}$, we could then get the linear transformation matrix $W^{\mathbf{T}}$ to estimate the independent comment as in the step 2 that implies;

Now we can understand working principle of the fastica algorithm. In reality, fastica performs relatively better than PCA in cases with more effecting factors such as light intensity and facial expression, representing the data distribution with more variety. However, it initially does not involve the classification.

3.2 Architecture diagram

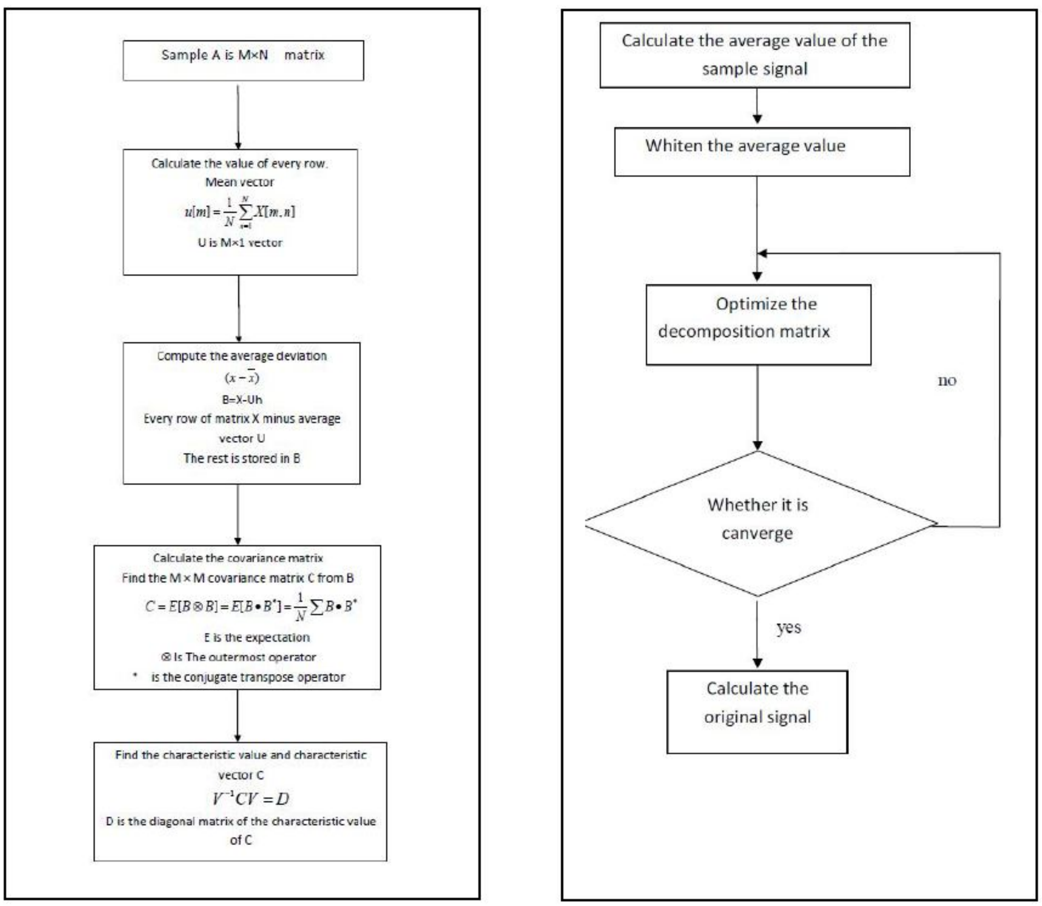

Figure 1: PCA and ICA procedure

4. Application of Face Recognition in Embedded System

So far as we discussed about is all about the algorithms applied in FDR, including its architecture and concrete running flow. In following chapter we will then transfer our eyes on the FDR in most embedded systems, covering its basic flows/ ideas and other improvement to enhance the results for instance the combination of hardware design corresponding to the algorithms running in software/the process conducted in the real-time video face recognition in embedded devices which make full use of its auxiliaries/along with the application of pca based face recognition embedded car system put in practice in reality to get more definite understanding of how FDR used.

4.1 Real Time Video Face Recognition for Embedded Devices

Compared with the flow of face recognition on general static images based systems, this part runs differently in most of the embedded devices such as some supervising system receiving input images through the outside sensors like cameras, which is exactly how most embedded devices work. In this chapter, we will show the overall flow in those devices and discuss the still remaining challenges.

4.1.1 General architecture of a video face recognition system

Most face recognition systems for static images and video images technology have the following classical workflow:

1. Detect the human faces in images.
2. Normalize the faces to the same size and in the plane orientation.
3. Extract the face features from the face area.
4. New test face images are processed with the existing faces storing in databases for comparison.

Figure 2 shows a typical architecture of a video face recognition system.

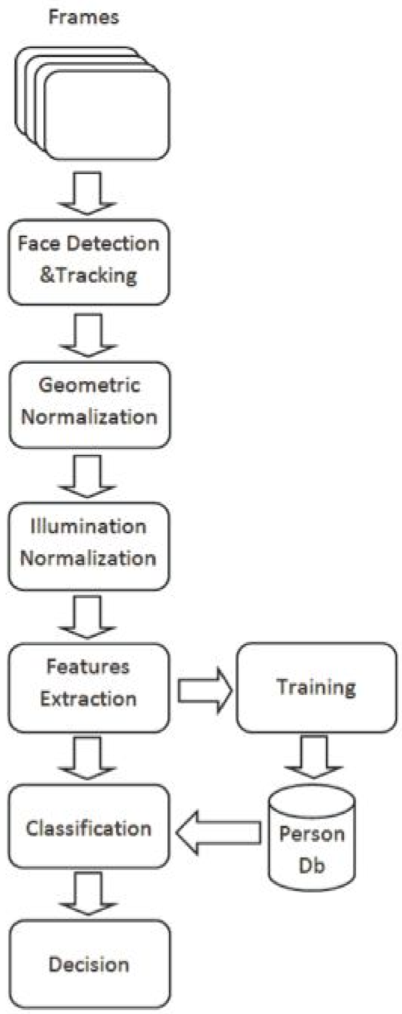

Figure 2: Video Face Detection and Recognition System Architecture

4.1.2 The difference between video cases and static images

The first difference between the these two technology is that video scenarios can use a tracking algorithm along with a detection algorithm in order to keep track of all the faces in the video sequence, which results in the three main advantages below:

1. The system can follow the faces across a wide range of changes in external factors .
2. The memory and time requirements of a face tracking algorithm are lower than those of a face detection algorithm.
3. Once a face in a particular frame is recognized with a high degree of confidence, that particular face does not need to be processed for the next frames.

4.1.3 New Methods of Characterization and Recognition of Faces

- Occlusions. Different components from the face may be occluded in the image by other objects or faces. These have to be addressed by the tracking algorithm.

- Capture conditions. Factors that are involved in capturing the image such as lighting conditions, camera characteristics, or quality of the captured image may have a big influence in the detection process.

– Face size or distance to subject. For video face detection and tracking consider the capture resolution and the distance from the capture equipment to the subject. For normal working resolution (qVGA, VGA) the faces can be very small even for relatively short distances.

For more specific details described in this field, we strongly recommend Real-Time Video Face Recognition for Embedded Devices [16] to look this topic in depth.

4.2 Brief Introduction to the PCA based Embedded Smart Car Security System

With the booming development of applications of many sophisticated embedded designs and techniques, the embedded systems in car also step closer and closer in the vision of engineers .A need for car security and reliability is highly demanding for usual consumers. And with the recent technologies and researches indicating the possibility of applying the face recognition inside the car system to boost the safety of the car meantime bring a new convenient but secure approach to the whole car industry.

In PCA based Embedded Smart Car Security System, face detection system (FDS) is used to recognize the face of the owner which is done by pca algorithm[22].FDS obtain images by one tiny digital cameras which can be hidden easily inside the car, whose role is to compare the detected images from the initially predefined images of the owner stored inside the database .After performing the algorithm and finishing comparing ,the system will automatically get stopped with the embedded controller platform at the same time using the GSM module embedded inside to inform the owner by texting .And the experimental results confirms the practical usage this system and the its relatively high reliability, prove in to be cheaper and more intelligent than the existing old car security system proving the way for future reforms of the embedded car security systems.

5. Face recognition: Process

1. First we input face images of 2049 samples for training and plotting out the mean faces and eigenfaces, displaying below:

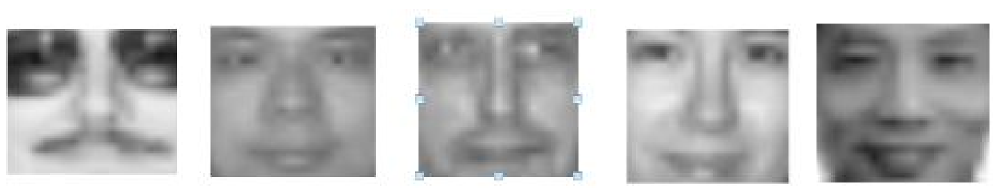

Figure 3: Training face images

2. After PCA ,the mean face is the first one, eigenfaces come along with the mean face

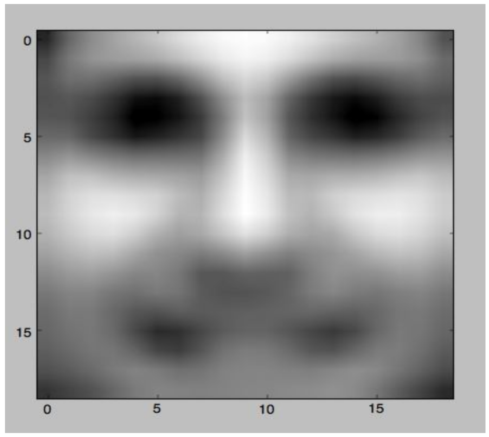

Figure 4: Mean face of 2429 training images

3. Come out the eigenfaces of the same number as images samples. Here we chose 16 eigenfaces as our basis of face reconstruction

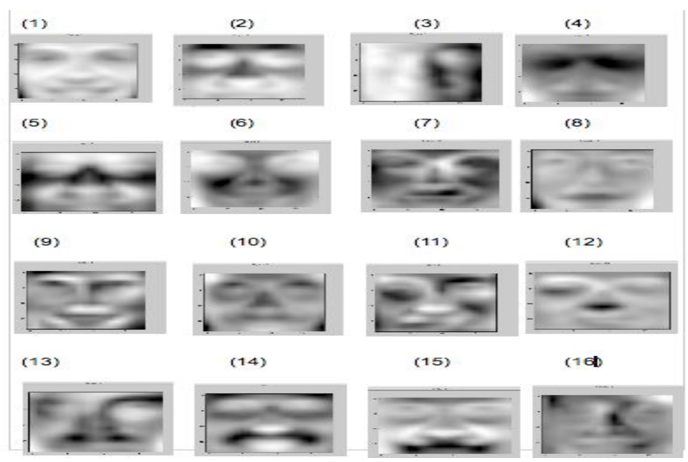

Figure 5: (1),(2),...,(16) are 16 eigenfaces from our training images

5.1. Results

We can reconstruct a face from its lower dimensional approximation. So let's see how many Eigenfaces are needed for a good reconstruction. I'll do a subplot with 10, 30, . . . , 310 Eigenfaces:

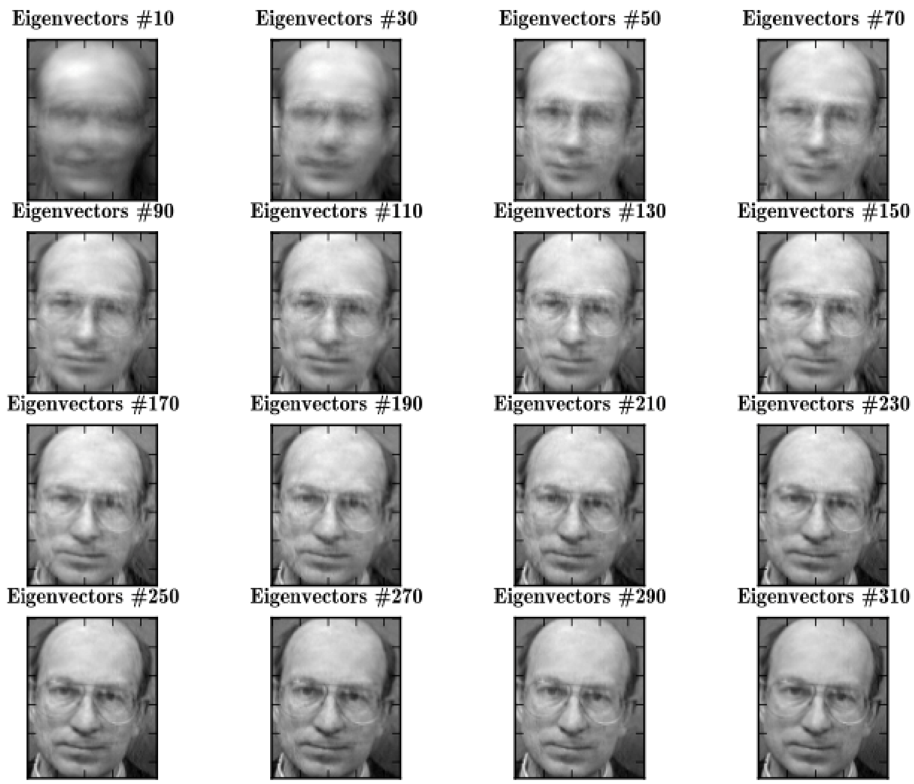

Figure 6: face reconstruction using eigenfaces of different numbers

10 Eigenvectors are obviously not sufficient for a good image reconstruction, 50 Eigenvectors may already be sufficient to encode important facial features. We'll get a good reconstruction with ap- proximately 300 Eigenvectors for the AT&T Face database. There are rule of thumbs how many Eigenfaces you should choose for a successful face recognition, but it heavily depends on the input data. [21] is the perfect point to start researching for this.

5.2. Problem Description

As for what we've done now, some errors and problems came along the way. We just listed in the figure 1 about all the problems appeared in our process regardless of their categories:

1. Principal component analysis is simply extraction the main feature of the object, abandoning extra data so in some cases it won't extract the exact right appropriate features, resulting in unclear transformed data.

2. The performance of PCA and ICA depend on given environment other than absolute conclusion.

3. The number of training face images is limited or dependent on the necessary people involved or may be involved in the future related to the actual purposes of use cases.

4. While taking facial expressions and other decorations on human faces into

consideration, it's more complex than what we've done using normal face images to be basis in face prediction and reconstruction. In real life, we can't ignore external influence such as environments and surroundings, so it's tougher just assume in researches that the receiving faces are normally structured.

5.3. Comparison of PCA and ICA

In our application, we divided the test images into 25 sets; each set contains 18 face images. After training, we use 25 sets to test whether our algorithms can recognize the faces and to what degree it can tell between the trained one and the test one.

Here is the comparison part of PCA and ICA, ending in table and plot format.

Table1: Recognition rate of PCA and FASTICA

Test set number	PCA	FASTICA
1	83.16%	87.37%
2	92.63%	95.79%
3	83.01%	82.50%
4	81.82%	82.27%
5	85.52%	87.65%
6	92.12%	95.01%
7	82.23%	83.45%
8	86.76%	90.03%
9	80.39%	82.58%
10	93.36%	94.58%
11	89.27%	93.45%
12	82.79%	85.68%
13	84.50%	87.14%
14	89.88%	90.78%
15	84.98%	86.53%
16	91.15%	94.23%
17	87.63%	90.14%
18	86.59%	87.93%
19	81.22%	83.43%
20	93.17%	95.42%
21	91.45%	93.51%
22	89.47%	88.25%

Test set number	PCA	FASTICA
23	91.34%	90.21%
24	86.59%	88.31%
25	92.42%	93.19%

The figure 7 shows the comparison plot of recognition rate of PCA and FASTICA

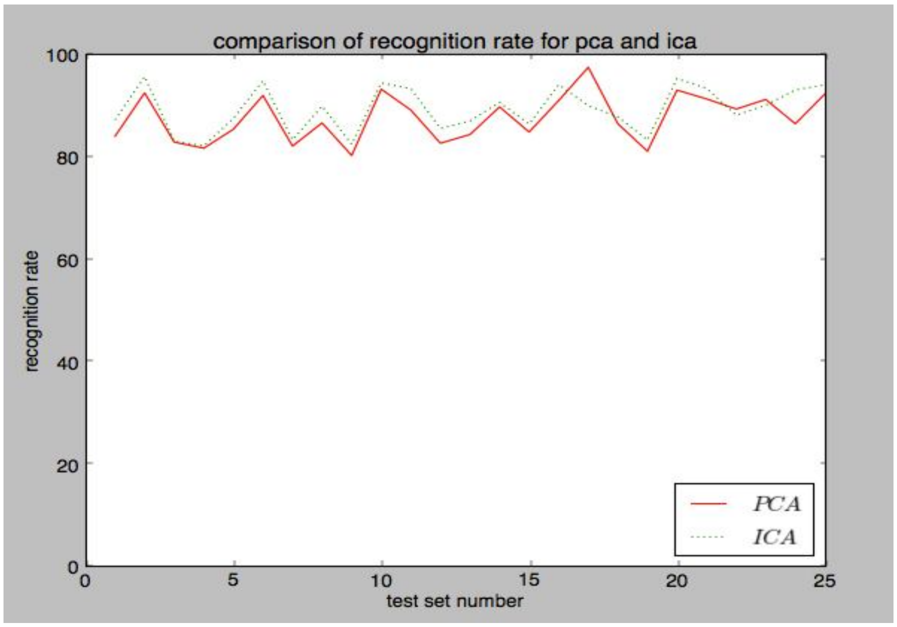

Figure 8: Plot of comparison for recognition rate

6. Summary

We initial studies are to demonstrate the face recognition for embedded system in detail and assess the recognition rate of PCA and ICA on the same face images. We then collected the result data and compared them in Figure 9.In presence of eigen faces and mean face we obtained before, we conducted the face recognition by those predefined faces to reconstruct the test images and get the shortest its Euclidean distance between the reconstructed face and the test face. These results above suggested that the FASTICA does better than PCA with regard to its higher rate. This time, we not only know more about the architecture in embedded system to conduct the face detection and recognition part, but also take a deeper insight of the most commonly used algorithms PCA and ICA and how they be applied in real life scenarios. In this way we could dig out more possibility of these algorithms and the potential of practical applications using them. However, It should be noted that this study has been primarily concerned with the static face images with no decorations and other background. So, the limitations of this study are clear that the findings do not imply that ICA performs better than PCA in every possible occasion.

7. Conclusion and Future Work

Taking all into account, the techniques in face detection and recognition are way more complex and vary from one to another. In this paper we simply spread some light on PCA and ICA and the face recognition part carried out in embedded devices meanwhile conduct a small comparison between the two, which indicates that the ICA performs relatively better than PCA. With the booming development of more sophisticated hardware and the decreasing prices and it ,we could apply more complex algorithms in practice like the embedded car system described in previous chapter of broader fields ,especially in embedded system ,which is specifically designed and used for specific purpose with fairly highly reliable performance. Furthermore, the combination of designed hardware with highly optimized algorithms running inside are drawing more and more people's attention for its precision and outstanding performance.

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