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라즈베리파이를 이용한 얼굴검출 및 인식 시스템 개발

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Development of a Face Detection and Recognition System Using a RaspberryPi

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요 약

사물인터넷이 4차 산업혁명을 주도할 새로운 기술로 각광받고 있으며, 이미 많은 기술과 제품들이 발표되어 인간의 삶의 질을 높이는 데 많은 기여를 하고 있다. 본 논문에서는 건물의 엘리베이터 등에서 얼굴 검출 및 얼굴 인식에 사용할 수 있는 시스템을 개발한다. 얼굴 검출 시스템은 하르 직렬 분류기를 사용하며, 얼굴 인식 시스템에는 수행 시간을 줄이기 위하여 본 논문에서 파이썬 언어로 구현된 주성분 분석(PCA)이 얼굴 인식을 위한 고유 얼굴(eigenface) 계산에 사용된다. 데이터베이스에 저장된 얼굴과 얼굴 검출 시스템의 결과로부터 얼굴을 인식하기 위하여 SVM 또는 유크리디안 측정이 사용된다. 제안된 시스템은 OpenCV를 사용하여 라즈베리파이 3에 구현된다. 본 논문에서 구현된 주성분 프로그램의 성능을 구하기 위하여 기존의 주성분 프로그램과 비교하여 얼굴 인식율과 수행시간을 비교하였다. 성능 평가를 위하여 ORL 얼굴 데이터베이스에서 40명의 얼굴에 대하여 각각 10 개의 이미지를 이용하여 학습에 200, 테스트에 200개의 이미지를 사용하였다. 본 논문에서 제안된 PCA와 유클리디안 측정을 이용한 경우 약 93%, SVM의 경우 약 96% 이상의 얼굴 인식률을 얻었다. 그러나 수행시간은 본 논문에서 구현된 PCA를 사용할 경우 약 0.11초, 기존 PCA의 경우 약 1.1초로 약 1/10로 수행 시간을 줄일 수 있었다. 그러므로 본 논문에서 개발된 시스템은 실시간 결과가 필요한 보안 시스템, 엘리베이터 모니터링 시스템 등에 적용할 수 있을 것으로 기대된다.

ABSTRACT

IoT is a new emerging technology to lead the 4th industry renovation and has been widely used in industry and home to increase the quality of human being. In this paper, IoT based face detection and recognition system for a smart elevator is developed. Haar cascade classifier is used in a face detection system and a proposed PCA algorithm written in Python in the face recognition system is implemented to reduce the execution time and calculates the eigenfaces. SVM or Euclidean metric is used to recognize the faces detected in the face detection system. The proposed system runs on RaspberryPi 3. 200 sample images in ORL face database are used for training and 200 samples for testing. The simulation results show that the recognition rate is over 93% for PP+EU and over 96% for PP+SVM. The execution times of the proposed PCA and the conventional PCA are 0.11sec and 1.1sec respectively, so the proposed PCA is much faster than the conventional one. The proposed system can be suitable for an elevator monitoring system, real time home security system, etc.

키워드

IoT, Face Detection, Face Recognition, Eigenface, OpenCV, RaspberryPi
사물 인터넷, 얼굴 검출, 얼굴 인식, 고유 얼굴, OpenCV, 라즈베리파이

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Ⅰ. Introduction

IoT is a new emerging and most import technology for 4^{th} industrial renovation and has been widely used in position based system, smart car, home network and security system, monitoring systems for water, gas and power in a smart city, and so on. In the era of world wide web people are in the center of network, but in the IoT a smart devices are in the center of network[1-3].

Many open source hardware platforms are announced for IoT implementation such as Arduino, Beaglebone black, Cubieboard, Galileo, Artik, RaspberryPi. RaspberryPi is a building blocks of a generic SBC(single-board computer) based IoT device and is a low-cost mini-computer with the physical size of a credit card. RaspberryPi runs various flavors of Linux and can perform almost all tasks that a normal desktop computer can do[4]. In addition, RaspberryPi also allows interfacing sensors and actuators through the general purpose I/O pins. And it supports Python out of the box[5].

An elevator is the most important riding tool in a building. If the elevator is more intelligent, it will bring more conveniences to the people. High-tech face recognition technology will bring revolutionary changes to make the elevator of buildings intelligent and convenient. RaspberryPi 3 can be used in a smart elevator monitoring system that automatically takes passengers to the floor of the building which they want to go[6].

In this paper, IoT based face detection and recognition system for a smart elevator, which shows the floor of the building that passengers live in is developed using OpenCV[7-8]. Haar cascade classifier is used a face detection system and in the face recognition system a proposed PCA algorithm written in Python is implemented to reduce the execution time on RaspberryPi 3 so that the passengers don't feel bored in an elevator.

We propose four types of the face detection and recognition system using the proposed PCA and conventional PCA supported in OpenCV with SVM and Euclidean metric for matching. To get performance evaluation of the proposed system, we train and test the system with 200 sample images for training and 200 sample images for testing in ORL face database. The time consumption of two PCAs are calculated.

This paper is organized as follows. Section Ⅱ explains the proposed PCA algorithm, and the face detection and recognition system is presented in section Ⅲ. Section Ⅳ shows the simulation results with four models and conclusions are described in section Ⅴ.

Ⅱ. The Proposed Principal Component Analysis(PCA)

Many algorithms have been developed to recognize objects and they extract information looking around some features or inside[9-10]. The extracted information or algorithms are called descriptor because they describe the features. So good descriptor is required to extract many useful features. PCA is well known as very effective descriptor for face recognition and can reduce D-dimensional feature vectors into d-dimensional vectors(D>d) with the least information loss[11].

PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components[12]. The number of principal components is less than or equal to the smaller of the number of original variables or the number of observations. This transformation is defined in such a way that the first principal component has the largest possible variance, and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to the preceding components. The resulting vectors are an uncorrelated orthogonal basis set. PCA is sensitive to the relative scaling of the original variables.

In this paper we develop a new PCA instead of the PCA supported in OpenCV. Fig. 1 shows the pseudo code of the proposed PCA.

```
# Pseudo code for PCA
step 1: Process the local face library
step 2: Calculate the mean
step 3: Subtract the mean from data matrix
step 4: Compute the covariance matrix
step 5: Find the eigenvalues and eigenvectors of the covariance matrix
step 6: Sort the eigenvalues from largest to smallest
step 7: Take the top N eigenvectors
step 8: Transform the data into the new space created by the top N eigenvectors
step 9: Get the Eigenfaces dataset matrix
```

Fig. 1 Pseudo code for the proposed PCA

In the first step, the system reads all the images in the local face library and saves them in a matrix. we create the matrix $\mathbf{A}_{(m,n=i\times j)}$ to save the image data, where the number of images, the number of pixel in an image, image length and width are m, n, i and j respectively. Each row of the matrix represents all the pixel information of an image and each column represents a dimension. In other words, dimension reduction represents the image with fewer columns. After processing the image of the local face library, the system displays all the images in a matrix called **data**. The dimension of **data** is $m \times n$ where $n = i \times j$.

The second step is to calculate the average of each dimension in the **data** matrix and we can obtain the mean face.

The third step is to subtract the mean of the corresponding column from each column of the **data** matrix, so that mean of the data from each column is zero.

In the fourth step, the covariance matrix represents the relationship between the different random variables, so it is to find the relationship between any two pixels in the image. If the covariance of two random variables is positive or negative, it indicates that there is a correlation between the two variables. If it is zero, the two variables are not relevant. By calculating the covariance matrix, we can obtain the relationship between the different pixels. The formula for calculating the covariance matrix in OpenCV is as follows, where mean_matrix is the result of the third step.

$$cov = mean\_matrix.T \times mean\_matrix$$

Because the covariance matrix is a real symmetric matrix in the fifth step, we can find all the eigenvalues and eigenvectors, which have n eigenvalues and eigenvectors.

The principal component is the eigenvectors with the largest eigenvalues. So in the sixth and seventh steps, we need to sort the eigenvectors according to the eigenvalues from large to small and then select different number of eigenvectors by the precision requirement. In our system, the dimension of the matrix is 92×112=10304 and the chosen eigenvectors are much smaller than n. In order to achieve the accuracy of the recognition rate, we only select 50 eigenvectors.

The principal component we choose is actually the projection matrix in eighth step.

Finally, we can get the eigenfaces dataset matrix and the data of test images under the eigenvectors.

III. The Face Detection and Recognition System Structure

The proposed system consists of a face detection and face recognition as shown in Fig. 2.

The face detection system captures the faces of visitors in an elevator. Face detection part contains facial detection using Haar classifier and image preprocessing aimed at Region of Interest(ROI)[13]. A histogram equalization is used to preprocess the face image. The histogram is a point operation that changes the grayscale value of the image by point, maximizing the number of pixels in each gray scale, making the histogram balanced. Histogram equalization allows the input image to be converted to an output image with the same number of pixels on each gray scale.

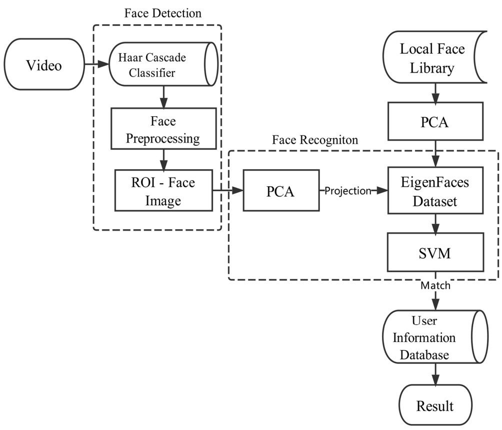


Fig. 2 Block diagram of the proposed system

The proposed PCA is applied to get the Eigenfaces dataset from the images. Next, we use one of Euclidean metric and Support Vector Machine(SVM) for matching[11].

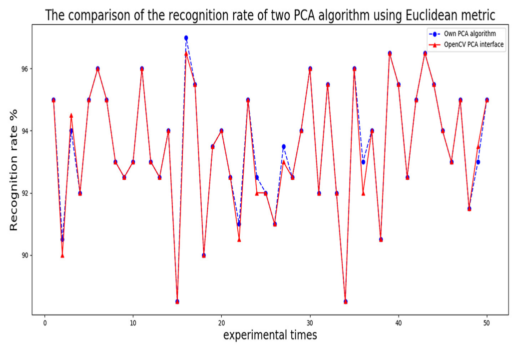
Ⅳ. Simulation Results

We implement 4 types of a face detection and recognition system with two PCAs(the proposed PCA in section Ⅱ and conventional PCA provided in OpenCV) and two matching algorithms(SVM and Euclidean metric). PP+EU is the proposed PCA+ Euclidean, OP+EU is OpenCV PCA + Euclidean, PP+SVM is the proposed PCA + SVM, and OP+SVM is OpenCV PCA + SVM.

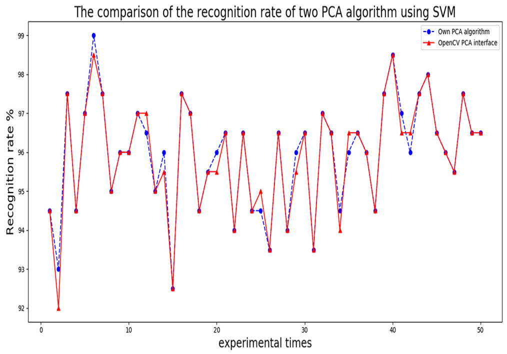
The ORL(Olivetti Research Laboratory) Database of Faces contains a set of face images used in the context of a face recognition project[14]. There are ten different images of each of 40 distinct subjects. For some subjects, the images were taken at different times, varying the lighting, facial expressions. All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position.

In order to get the performance of each system, the following 3 steps are carried out: 1) Use ORL face database as a training and test data sample. 2) Select randomly the 5 faces of each person in the database as training samples and the rest of 5 faces as test samples. So there are a total of 200 training samples and 200 test samples. 3) All 200 test samples are all recognized, this process is called a random test. Then we observe whether the 200 test samples are accurately identified. This experimental process is done 50 times for every 4 systems.

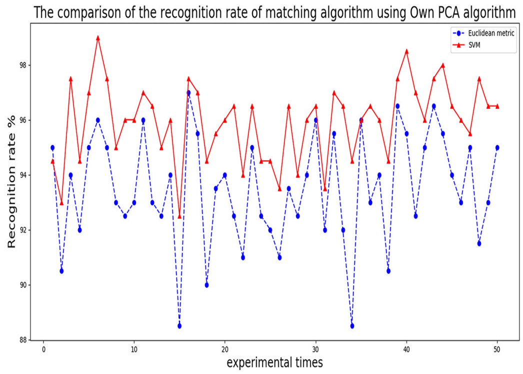
Fig. 3 shows the face recognition rates of 4 systems for every experiment. As shown in Fig. 3 (a), PE+EU and OP+EU get almost same results of around 94% and PP+SVM and OP+SVM in Fig.3 (b) show almost same results of around 96%, and they have same trends as well. And Fig. 3 (c) says that the proposed PCA with SVM(PP+SVM) has better face recognition rate than the proposed PCA with Euclidean metric(PP+EU).



(a) The recognition rates for two PCAs using Euclidean metric



(b) The recognition rates for two PCAs using SVM



(C) Comparison of the proposed PCA between Euclidean metric and SVM

Fig. 3 Face recognition rate

Table 1 shows the average recognition rates, where ARR is the average recognition rate. PP+EU has a little higher rate of 0.4% than OP+EU and PP+SVM has higher result of 0.13% than OP+SVM. These results mean that the proposed PCA is a little better than the conventional PCA for the face recognition.

Table 1. Recognition rate

Type	PP+EU	OP+EU	PP+SVM	OP+SVM
ARR	93.99 %	93.57 %	96.23 %	96.10 %

Table 2 show the average time consumption in PCA, where ATC is the average time consumption. PP has 0.11s, and conventional OP has 1.11s on RaspberryPI 3. The proposed PCA can reduce it by removing the complex interfaces to connect to other functions and data type conversion time. Therefore our proposed PCA is more suitable to real time system or embedded systems that need faster execution time.

Table 2. Time consumption of PCA

PCA type	PP	OP
ATC(s)	0.110	1.110

Ⅴ. Conclusion

We implement a new PCA written in python that can run on RaspberryPi 3 for a smart elevator and design 4 types of face detection and recognition system.

The ORL database which contains 400 images is used to get the face recognition rate. The simulation results say that the proposed PCA in this paper is better than the conventional PCA in OpenCV, and the combination of the proposed PCA and SVM has the best performance. The execution times for two PCAs are 0.11s and 1.11s and this shows the proposed PCA is 10 times faster than the conventional PCA. Therefore our proposed PCA is more suitable in application field such as real time system or embedded systems that need faster execution time.

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