Door Security using Face Detection and Raspberry Pi

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Abstract. With the world moving towards advanced technologies, security forms a crucial part in daily life. Among the many techniques used for this purpose, Face Recognition stands as effective means of authentication and security. This paper deals with the user of principal component and security. PCA is a statistical approach used to simplify a data set. The minimum Euclidean distance found from the PCA technique is used to recognize the face. Raspberry Pi a low cost ARM based computer on a small circuit board, controls the servo motor and other sensors. The servo-motor is in turn attached to the doors of home and opens up when the face is recognized. The proposed work has been done using a self-made training database of students from B.K. Birla Institute of Engineering and Technology, Pilani, Rajasthan, India.

1. Introduction
Face recognition, which deals with recognition and authentication of a face, is a modern security feature and a field that has been studied extensively for a long time. Used in most of the real world applications, varying from surveillance to security and access, face recognition has found many techniques for itself. Principal component analysis (PCA) is one of the most extensively used and simplest procedure for face recognition. The PCA algorithm uses mathematical tools such as eigen value, eigenvectors, eigen faces and euclidean distance for recognition. As each image can be viewed as matrix of dimension M x N, this process is quiet handy and easy to implement. The image with the least euclidean distance predicts the most accurate face. As our field of interest lies only the facial part, we use Viola Jones method for face detection. This security technique finds lot of applications, home security being one of them.
2. Viola-Jones Method
Viola-Jones method is a widely used method for object detection. In this proposed work, Viola Jones method is used to detect and capture the facial part. This method works by looking for feature. Each feature are represented by small set of rectangles, group of pixels contained in it. The face in this method is represented by a rectangle, which is formed by the set of smaller rectangles. The basic reason for use of this method is that the detection in this case is very fast.

3. Principal Component Analysis
Principal component analysis, a method to abridge huge high dimensional data, is a statistical approach for face recognition and image compression. The PCA uses mathematical tool such as eigenvector, eigen faces, euclidean distance, covariance matrix for its functioning. This 2-dimensional data feature extraction method, computes feature of each image in training set into their respective covariance matrix. This covariance matrix is used to determine the eigenvector and eigen value for each corresponding image. From the derived values, eigenvector corresponding to the highest eigen value is considered. This eigenvector is the principal component of that image and is projected in the face space. Similarly, eigen vector of the test image is calculated and the euclidean distance is evaluated. The euclidean distance is the average distance between the test vector and the training set. The minimum distance represents the most similar image.

4. PCA Algorithm
Principal component analysis, a mathematical tool is largely used in face recognition using different statistical approach. PCA instead of acting upon quantized image works directly on unquantized image using complexity reduction algorithm.

Let the two dimension face image be represented by I(x, y) of dimension M*N. This image can be represented by vector of reduced dimension M*N. Each high dimensional image in the training set is represented by a vector of coefficient in a free space of reduced dimension.

4.1. Training Dataset

4.1.1. If we considered the dataset of image to be \{I_1, I_2, I_3, \ldots, I_N\}, then the average face for the training images can be give as mean of the images, that is Average face J=1/N \sum_i I_i.

4.1.2. The next step is to calculate the covariance matrix. It represents the degree up to which the faces are linearly correlated w.r.t average faces.

\[
D = I_i - J
\]

The covariance matrix C is,

\[
C = DD^T
\]

4.1.3. The covariance matrix is used to determine the eigenvector and eigen value for each image in training set. Therefore, the eigenvector and eigen value associated with each image is given by:

\[
CV_i = \mu_i V_i
\]

\(V_i\) is the \(i^{th}\) eigenvector and \(\mu\) is its eigen value.

4.1.4. For each image we sort the eigenvector in descending order with respect to its eigen values. Henceforth, we keep only \('k'\) eigen vector starting from top of the descending list.
4.1.5. Eigen faces are ghostly facial image represented by $U_i$ and is given by

$$U_i = D V_i$$

4.1.6. The training face image is now projected into the Eigen face space by

$$W_i = U_i (I_i - J) = U_i^T D$$

Where, $W_i = \{W_1, W_2, W_3, ..., W_N\}$ represented feature weights for training images. These weights are represented by vector $P_e$.

4.2. Sample Test

The Process flow adopted for testing is a mentioned:

4.2.1. Obtain the test image from camera and detect the face using Viola Jones method.

4.2.2. Project the test image in the face space and calculate the feature vector and weight. The weights are given as

$$W_{test} = U_i^T (I_{test} - J)$$

Here, $W_{test} = \{W_1, W_2, W_3, ..., W_N\}$ feature represent corresponding to value of $i$, i.e. the $i_{th}$ eigen faces. These weights be represented by vector $P_{test}$.

4.2.3. Calculate euclidean distance between the test feature vector and all training feature vector of the training set. The Euclidean distance, average distance is given by:

$$Y_i^2 = (|P_{test} - P_i|^2)$$

Where, $i = \{1, 2, 3, ..., K\}$. This distance gives the similarity between the test image and training image.

4.2.4. Find the minimum euclidean distance. The one with minimum euclidean distance describes the most similar face.

5. Hardware Interfacing

The face recognition algorithm interacts with the different home appliance such as camera and servo motor using the Raspberry Pi. The Raspberry Pi, a series of credit card sized single board computer, is a low cost ARM based computer. Its GPIO ports facilitates the interaction between the software and hardware.

A specially configured Linux operating system from MATLAB is used in this case for communication between the two parties, the hardware and code. The camera linked with the Raspberry Pi capture the image. The MATLAB using Viola Jones method detect the face. The detected face is matched with the training facial dataset using MATLAB code. If the face is recognized MATLAB communicates with the Raspberry Pi. Which in turn instructs the servo motor to open the doors. If the face is not recognized, MATLAB instructs the Raspberry Pi to turn on the alarm.

6. Diagrammatic Representation Flowchart

6.1. Diagrammatic Representation
Figure 1: Representation of complete workflow taking into consideration the software and hardware part.
6.2. Data Flow

![Diagram of data flow process]

- Start
- Read Training dataset database
- Compute the covariance matrix
- Evaluate Eigen value and Eigen vector of covariance matrix
- Keep the highest k Eigen vectors (Eigen faces)
- Project the Eigen vector in free space
- Read the test image
- Calculate the Eigen vector of test image
- Project test feature vector in the Eigen face space
- Calculate the minimum Euclidean distance (Most similar image)
- Matched?
  - No: Warning
  - Yes: Open the gate using Raspberry pi

Figure 2: Process flow for the proposed work.
7. Experimental Result
The complete proposed model works efficiently with the self-trained face database at different as well as similar facial expression. It is also found to work successfully with multiple faces.

In case when multiple faces are in consideration, the face which is most similar with that in the training database is recognized.
8. Conclusion

In this research, principal component analysis plays the major role. It is considered as the best approach as it not only decrease computational complexity but also support compact data distribution. Though the PCA efficiency is effected by variation of light intensities, increasing the number of training images with variation can neutralize the fluctuation. Care must be taken in increasing the number of training images as the neutralization effect is possible only up to a limit. The proposed work works well with different image format but variation in image size limits the work. The interaction between the PCA algorithm and the hardware is quiet commendable. Thus, the principal component approach provides a solution that fits best in the proposed work.

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