ISSN: 2085-6407

Jurnal Ilmiah Teknik Komputer

Volume 1 Nomor 2 Mei 2010

Kelompok Keilmuan Teknik Komputer
Sekolah Teknik Elektro & Informatika
Institut Teknologi Bandung

Eigenfaces Method Implementation on Face Recognition Application with Different Distances

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Abstract. Face recognition system is one kind of biometric technology. This system use a computer to analyze people's face structure which was captured by a camera/ video camera then compare it to a provided face database. Face recognition system has come to a wide area drawing attention for researchers since a long period. A neural network system was used for detecting and recognizing a face that were taken from three different distances. The result of using NN does not give good performance. Face images were taken in a frontal position. Therefore, a face recognition system that could recognize faces which were taken from different distances is important. In this research, the author made a face recognition application that can recognize faces which were taken from three different distances (1/2 meter, 1 meter, 2 meter) using eigenfaces method. This application was made using Java language programming and OpenCV library.

Keywords: *eigenfaces, face recognition, haar classifier*

1 Introduction

In the beginning, computer was intended to use as a tool for doing some easy and quick computations. The data processing was only limited to text. But as the period past, the computer's function was developed. In this time, computer not only can process data and information which in text form, but can process images, animations, audio, and videos. A technology which this past few ears has become one of an interesting research is biometric technology. Biometric technology is an automated method to identify human based on biological or behavioral characteristics. Face recognition is one kind of biometric technology. Face recognition system has come to a wide area drawing attention for researchers from different backgrounds. In this time, face recognition system has a number of areas, like forensic, psychology, and security. Algorithm which used in face recognition is quite a lot and varies. A neural network system of back propagation was used for detecting and recognizing a face that were taken from three different distances [4]. Face images were taken in a frontal position. A neural network system required the application to run some training on the system to gain a successful face recognition result, besides defining some parameters like hidden layer and goal. In this research, we made an application that can recognize faces taken from three different distances (1/2 meter, 1 meter, 2 meter) using eigenfaces method. Face images used were still images and taken in a frontal position.

2 Face Recognition Technology

Face recognition system has come to a wide area drawing attention for researchers from different backgrounds until this time. Nowadays, face recognition system has been used in a number of areas, such as biometric recognition system, images and digital videos database searching and indexing, security, video conference, and human computer interaction application. Many researches have been conducted to find a good algorithm and method for face recognition. But it still leaves questions and problems waiting to answered and solved. The main problem of face recognition has the same age as computer vision, because of the important topic and theoretic attention from many researchers. Besides, face recognition always be the main focus of research because of the inconstant behavior and it is the main method to recognize someone. The first face recognition system was Kohonen, which showed that a simple neural network system can be used to recognize a face form a normalized image. The neural network system was used to do some computations on a face image by calculating eigen vectors from a face image's auto-correlation matrix. These eigen vectors were known as eigenfaces. Kirby and Sirovich (1989) introduced an algebra manipulation to calculate eigenfaces directly and showed that only less than 100 lines code needed to do an accurate normalization. Turk and Pentland [5] showed some errors which were occurred when eigenfaces can be used to detect faces in complicated background and determine the exact location and scale of a face in an image. Researchers has done much development and proposed some method for face recognition which refers to frontal image face recognition, small image database, and limited image condition in last 20 years. Meanwhile, some researchers doing research on bigger image database, multi pose image face recognition, and real-time face recognition.

2.1 Eigenvector and Eigenvalue

Let A be an n x n matrix. Then a nonzero vector *x* in n-dimensional nonzero vector R^n is called an eigenvector of A, if Ax is the scalar multiplication of x, which $Ax = \lambda x$ *for* scalar λ. Scalar λ is called an eigenvalue of A and x is called an eigenvector which associated with λ. To calculate eigenvalue from an n x n matrix A, we can write down $Ax = \lambda\, x$ as $Ax = \lambda\, Ix\ \lambda\ (\lambda\, I - A)\, x = 0$. Equation $(\lambda\, I - A)\, x = 0$ will have a solution if $\det(\lambda\, I - A) = 0$. Equation $\det(\lambda\, I - A) = 0$ is called characteristic equation A. These are some important things to remember about eigenvalue and eigenvector [1][3]:

1. Eigenvalues and eigenvectors are defined only for square matrices, for example the number of rows must be equal to the number of columns in the matrix.
2. The number of eigenvalues associated with the matrix is equal to the size of the matrix, for example there will be 2 eigenvalues for 2 x 2 dimension matrix. In general, if the size of the matrix is 'n x n' there are 'n'

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eigenvalues associated with the matrix and each one has an associated eigen vector with it.

3. According to the definition, the zero vectors can not be an eigenvector. However the real number 0 can be an eigenvalue of a matrix.
4. Every eigenvalue has an infinite number of eigenvectors associated with it, as any nonzero scalar multiple of an eigenvector is also an eigenvector.
5. A matrix is invertible if and only if none of its eigenvalues is equal to zero.

2.2 Eigenfaces for Face Recognition

Much of previous work on automated face recognition has ignored the issue of face stimulus aspects which are important for identification, assuming that predefined measurements were relevant and sufficient. This suggested that an information theory approach of coding and decoding face images may give insight into the information content of face images, emphasizing the significant local and global face features. In the language of information theory, if we want to extract the relevant information in a face image, encode it as efficiently as possible, and compare one by one face encoding with a database of models encoded similarly. A simple approach to extracting the information contained in an image of a face is to somehow capture the variation in a collection of face images, independent of any judgment of features, and use this information to encode and compare individual face images. In mathematics, it means getting principal component from distributed face or eigen vectors of covariance matrix in a set of face image training. These eigenvectors are a set of features which characterize the variations of face images. Each location of a face give a contributions to determine eigen vectors, so we can represent those eigen vectors as a ghostly face which is called eigenfaces. Each face image in the training set can be represented exactly in terms of linear combination of the eigenfaces. The number of possible eigenfaces is equal to the number of face images in the training set. However the faces can also be approximated using only the "best" eigenfaces that have the largest eigenvalues, and which therefore account for the most variance within the set of face images. The first idea of eigenfaces is represented by Sirovich and Kirby which efficiently represent face images using the principal component. A set of face image collection can be approximately constructed by having some small collection of each face weight and a small set of standard face image. Next research was conducted by Turk and Pentland [6] which using eigenfaces to detect faces in complicated background and determine the exact location and scale of a face in an image. Principal analysis for face recognition is based on the information theory approach. Here, the relevant information in a face image is extracted and encoded as efficiently as possible. In mathematical terms, the principal components of the distribution of faces or the eigenvectors of the covariance matrix of the set of face images, treating an image as a point (vector) in a very high dimensional face space. These vectors define the subspace of face images, which we call "face space". Each vector is of length N2, describes an N x N image, and is a linear combination of the original face images. Because these vectors are the eigenvectors of the covariance matrix corresponding to the original face images, and because they are face-like in appearance, we refer to them as "eigenfaces". Some examples of eigenfaces are shown in Figure 1.

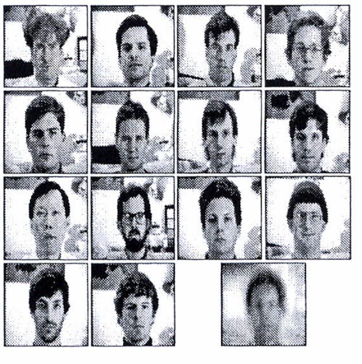


Figure 1 Examples of eigenfaces

The eigenfaces approach for face recognition process is fast and simple works well under constrained environment. It is one of the best practical solutions for the problem of face recognition. One of the limitations for eigenfaces approach is in the treatment of face images with varied facial expressions and with glasses. Also as images may have different illumination conditions. An image can be represented as the intensity value of each pixel. For example, the dimension of an image is m x n. It means the image is contained pixel grid in m rows and n columns. Suppose (contained images besides the positive samples, for example sceneries, walls). The training information then converted to a statistical parameter model. Haar algorithm uses a statistical method to do the face detection. This method uses the simple Haar-like features and a boosted tree classifier. The classifier uses an image that has a determined size (commonly 24x24 pixels). Haar works using a sliding window technique (size 24x24 pixel), scanning on the face image to find a face-like image when detecting faces. Haar has a scaling capability so it can find a face image estimation that has a size bigger or smaller than the image contained in the classifier. Each feature of Haar-like feature is defined by the feature shape, like the feature coordinates or size. The Haar-like feature shape variations are shown in figure 2.

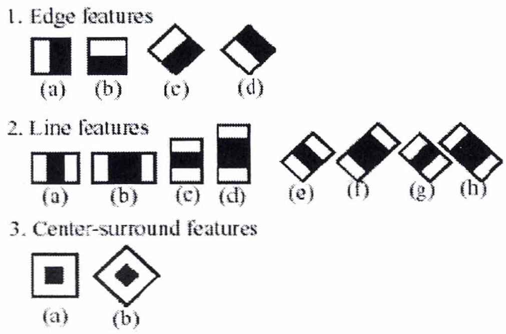


Figure 2 The Haar-like feature shape variations

Each Haar-like feature consisted of black and white area. The value of Haar-like feature is the difference between the grey level pixel values in the black and white area.

3 Result and Discussion

The examination process used 300 face images (taking by a digital camera) as input to the application. The face image type is JPG. Face images were still images, taken in a frontal position, with varied illuminations, simple background, and without expression. Each image was taken in three different distances (1/2 meter, 1 meter, and 2 meter). The distance is defined from the distance between the digital camera and the object. Some of the experiment results are shown in figure 3a and 3b.

Recognized Images	Face Detection Result	Database Images
 Image 10	 Score = 62	
 Image 11	 Score = 69	
 Image 12	 Score = 100	
 Image 112	 Score = 53	
 Image 113	 Score = 100	
 Image 114	 Score = 27	
 Image 136	 Score = 100	

Figure 3a Some experiment results

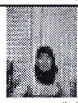
Recognized Images	Face Detection Result	Database Images
 Image 137	 Score = 76	
 Image 138	 Score = 67	
 Image 163	 Score = 73	
 Image 164	 Score = 100	
 Image 165	 Score = 49	

Figure 3b Some experiment results

As from figure 3a and 3b, the highest accuracy level for face recognition is 100 (as shown with the score) and the lowest is 27. Score 100 means that the recognized face image is the image that is used as database. For example Image 12 which has score 100, it is because the image that was used in database is Image 12 for the same person (Image 10-12). Each person has one image (from the other three images) that is used for database. The total amount of database images is 100 images. Score besides 100 would happen if the recognized image is not the database image (for the same person). For example Image 138 which has score 67, it is because Image 138 is not the image that was used in database. The highest score percentage for the face recognition is 33.3% and the percentage of the score besides 100 is 66.7%. A low score doesn't show that the face recognition process failed, because the person's identity (appear in a name) that comes with the result for each person is right and in the upper level order. As seen in figure 3a and 3b, if the image database was taken from distance 2 meter, then the face recognition score for recognized image that was taken from distance 1 meter will bigger than the score for recognized image that was taken from ½ meter distance. This happened almost in all recognized images for the experiment, except for Image 25, 43, 55, 61, 193 and 235. If the image database was taken from distance ½ meter, then the face recognition score for recognized image that was taken from distance 1 meter will bigger than the score for recognized image that was taken from 2 meter distance. This happened almost in all recognized images for the experiment, except for Image 15, 117, 147, 270 and 300. High score besides 100 will happen in face recognition that has the database images which were taken from distance 1 and 2 meter. Illumination is the most important thing to concern, because it will affect the face recognition result. An image that was taken form distance ½ meter which has great illumination had a high enough score besides 100 (Image 79, 82, 85, 160, 166 and 190).

4 Conclusion

Eigenfaces approach is one of the face recognition methods. After the application was tested and analyzed, we conclude that the application can accommodate the Eigenfaces method to do face recognition. From 300 face images used as sample images (gender and age are vary) gives the level efficacy equal to 33.3% for the face recognition score 100 and 66.7% for the face recognition score besides 100. Some factors causing the happening of score besides 100 are illuminations and in-accurately face position (the face not in the right frontal position). This application can be used to do face recognition efficiently for small face image database. In future we plan to refine the application so it can be used to do face recognition for bigger face image database, has more accurate face recognition result, and can be used to do real-time face recognition.

5 References

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ISSN 2085-6407