Experiments with Face Recognition Using a Novel Approach Based on CVQ Technique

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Abstract. Face recognition techniques attempt to identify faces according to the patterns of mouth, lip, eyes and so on. However, the effectiveness of existing approaches degrades in presence of uncontrolled conditions such as variations of background light and image sizes. To deal with this problem, we propose a novel approach based on Classified Vector Quantization (CVQ) technique. The new approach divides images into some blocks and each block is classified into several patterns. Then, the Vector Quantization (VQ) technique is applied on the vectors of each pattern. In order to evaluate our approach, we have conducted a family of experiments on some standard image databases, MIT, YALE, and AR. The results demonstrate that the new approach is steadily capable of identifying faces in different situations.

Keywords: Face Recognition, Classified Vector Quantization (CVQ), Vector Quantization (VQ).

1 Introduction

Currently, due to the increment of violence and crime rate, the usage of systems to establish security and safety is a critical requirement to the current human's life [1]. To deal with this requirement, face recognition of convicts is considered as the major purpose in development of such systems [6]. In addition, since the events of September 11, the process of development and implementation of automated biometric systems have been noticeably increased [6, 7]. Moreover, there are many practical situations in which we need to the techniques of pattern recognition, and in particular face recognition. The wide range usage of these techniques in commercial and law enforcement applications, such as biometric authentication [7], video surveillance [39] and information security [1] has made it a popular and significant area of research. Nowadays, we are capable to identify people through automatic recognition techniques based on physiological and characteristic behaviours, such as finger print [28, 29], iris [2, 3, 4], ear [5], vein face [27], and so on. Although many techniques have been proposed for pattern recognition [30], especially face recognition [31, 32, 33], and a number of studies [34, 35, 36] have been performed in the literature to evaluate and compare the existing techniques, there is still a long road ahead to achieve optimal approaches.

There are various natural characteristics in human's body such as finger print, ear, iris, and similar other parts whose structure are unique for each human [7]. The uniqueness of the structure for the mentioned body features can be used to recognize and to distinguish people from each other [37]. Ear recognition [5, 38] is a new class of biometrics that has certain advantages over most of the established biometrics; it has a rich and stable structure that is preserved from birth into the old ages [5]. Iris recognition [2, 4, 9, 8] is one of the most accurate biometric systems when a high level of security is required. Therefore, designing such systems has attracted the attention of a large number of researches [2, 4, 8, 9]. Unlike of other biometric methods, recognition based on human's face does not have any reliable and dependable mechanism that controls any undesirable conditions in the image of the face. These conditions include (1) changing the position of the face, (2) changing the size of the image, (3) the lack of sufficient light, etc. In ear recognition method, we need a half face image of each person. Hence, it is not an appropriate technique for facial expression recognition [5, 38]. In iris recognition method, by closing the eyes, the recognition process fails and we still need a reliable control mechanism. In addition, if the recognition relies only on the geometric structure of face [25, 26], it will also need a reliable control mechanism because face in various angles loses its potential to be recognized properly [10].

In this paper, we propose a novel approach for face recognition based on Classified Vector Quantization (CVQ) [17, 18, 23, 24] technique. At first step, this approach divides the face image into some blocks, converts each block to a vector, and classifies the vectors into some predefined patterns. These patterns are the major and common curves on the faces of different people. At second step, it uses Vector Quantization (VQ) [11, 13, 14, 15, 16, 19] on the classified vectors of each pattern. The selection of the predefined patters significantly affects the performance of this approach. To evaluate the functionality of the proposed approach, we have conducted experiments on some standard image databases used in the experimental studies in the literature. The overall results showed that the proposed approach is capable to recognize images with an appropriate recognition rate.

The remainder of this paper is organized as follows. In Section 2, we introduce the face recognition problem. Vector quantization techniques and classified vector quantization technique are described in Sections 3 and 4 respectively. In Section 5 the proposed approach is presented. The experimental setup and the obtained results are discussed in Sections 6. Finally, some concluding remarks are outlined in Section 7.

2 Face Recognition

Face recognition has been used in different fields of security and protection, namely automated crowd surveillance [39], access control [6], identification of convicts [40], face reconstruction [43, 44, 45] and so on. Thus, it has been one of the challenging issues in the last decade and it is a necessity in our current life.

In computer vision, there are two important methods whose purpose is face recognition. The first group is holistic appearance base methods, including PCA [46, 47], and LDA [48, 49]. In these methods, a facial image is considered as an instance in N dimensional feature space, where N is the number of pixels in the image. The second group is local facial based methods such as elastic bunch graph matching. In these methods, a set of orthogonal basis vectors, that maximize the variance of facial image data, are obtained by Eigen decomposition of the scatter matrix of facial images. Combination of the two above methods, that are named hybrid methods, can be used for face recognition purpose.

Face recognition algorithms have focused on some unique properties of face [7] such as iris, ear, skin, etc. Among the different components of face, brow is the most important for face recognition purpose. According to the existing studies [16, 17, 18, 19], all of the face features or components do not have equal effect in the effectiveness of face recognition process. Most of the experimental results and researches [37] showed that in the field of face recognition, nose and mouth are more important than eyes. Although brows have equal effect in face recognition as compared with other face components, less attention has been considered toward the effects of brows against the other face features [11]. Thus, an algorithm that utilizes all of these features together would perform better than existing ones. The proposed method in this paper takes different features of the face into account to improve the efficacy of face recognition.

3 Vector Quantization

The Vector Quantization (VQ) technique [22] was first developed for image processing to compress the images [13, 14]. Codebook is a 2D array which is initialized randomly by the vectors of some of the training images. The number of columns in the codebook depends upon the size of the blocks of image and is usually considered as 9 or 16. In the decompressing phase, each code word by index *i* is replaced by the code word with index *i* in the codebook. One of the benefits of this technique is its low computational complexity. However, it is considered as a lossy technique. The CVQ [17, 18, 23, 24] and TSVQ [41, 42] are two major extensions of this technique.

When applying the VQ technique in face recognition, each block of the original image is identified with an index (number of the nearest code word in codebook). The response time is an important factor in real time applications [15] and VQ-based recognition provides reasonable response time in these situations.

In Vector Quantization (VQ) technique, the original image is partitioned into several blocks with the size of n × m. Then, then each block is arranged in the form of a vector using the row major or the column major method. In the next step, the codebook is updated using the obtained vectors of the image. Each row of this matrix is called a code word. Next, the difference between each vector of the original image and each code word in the codebook is computed by using of Euclidean distance in Equation (1):

$$D(B_i, C_j) = \sqrt{\sum_{k=1}^{n} (B_{i,k} - C_{j,k})^2} \tag{1}$$

In this equation, B_i is a vector from the original image, C_j is a code word from the codebook, $B_{i,k}$ is the kth element of the ith vector, and $C_{j,k}$ is the kth element of the jth code word. By this computation, the nearest code word to each vector with respect to the Euclidean distance is found. Finally, code words are updated by the centroid of all training vectors, which were mapped during coding [11]. Finding the optimized codebook is the major goal in VQ technique. It has been shown [12] that the design of VQ is optimal. This design is illustrated in Figure 1.

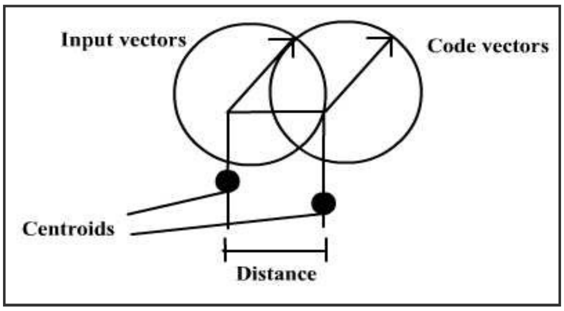

Fig. 1. Optimality of VQ design

4 Classified Vector Quantization

Edge is a very significant feature perceptually in an image. In our proposed method, we have used edge information for face recognition. Each coding technique that preserves the edge information is preferable because it has been proved [50] that the human's eye can recognize objects through their edges and this is adapted in image processing methods. The Classified Vector Quantization (CVQ) technique has been proved [17] to be an efficient technique for lossy image compression at low bit rates. CVQ technique can be used to reduce the computational complexity of VQ technique [11]. In this technique, each input vector is classified into a class. Then VQ is applied on vectors of each class [24]. Using this technique, there would be two indexes for each input vector: One for specifying the number of class and another for specifying the index of the nearest code word in codebook. This idea is shown in Figure 2. With CVQ technique, when applied to the face recognition, input vectors can be partitioned into some predefined patterns and then quantization is used for all vectors of each pattern. Since CVQ technique classifies the vectors in several classes, it is more precise than VQ.

5 The Proposed Approach

VQ technique can be very reliable in face recognition based on human's skin because of the correlation of human's skin. But the main problem is when the number of training vectors of images is increased, VQ cannot distinguish among vectors because many of the vectors happen to be similar and the differences can be hardly observed. As a result, the efficiency of this technique degrades and it is the only limitation in the usage of this technique. Now, each block of the test image is indexed with the number of a pattern. When all of the image blocks were indexed, VQ technique is applied over all vectors that were classified for each pattern.

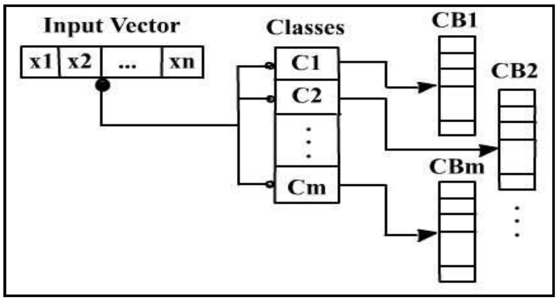

Fig. 2. A schematic of CVQ design

In order to deal with the issues of the VQ technique, CVQ can be applied. In our proposed approach, each block of the original image, the human's face, is compared with several predefined patterns. These patterns are defined according to the curves that are most seen in faces of each human. They can be extracted from a random number of faces using a pattern recognition approach like neural network. Figure 3 depicts some samples of patterns.

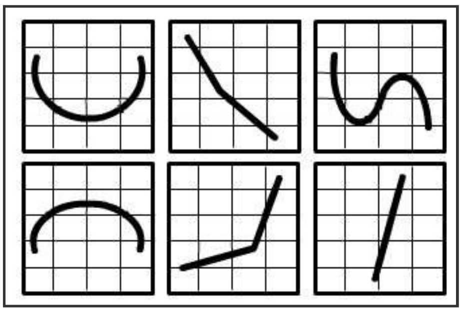

Fig. 3. Some samples of patterns

Several studies [11, 20, 21] have shown that different features and components of the face can have unequal and various effects to the face recognition. Hence, taking all features of the face together into account has much potential for a face recognition technique to lead to better results. As a result, edge detection in face and also skin correlation can be considered together to enhance the face recognition process and improve the results. The

Classified VQ technique enables us to consider the mentioned two features of the face simultaneously. This capability exposes the importance of CVQ technique in face recognition.

According to the above descriptions, we can present our method in the following steps:

1. The image is cropped to fit in the desired size.
2. The image is converted to the grayscale.
3. We need to detect the edges of the faces related to each original image. For example, Sobel filter can be used for this purpose.
4. According to the previous step, we can classify each block of the original image to one of the predefined patterns. Suppose that all blocks have been classified into classes C_1 to C_n. Each class corresponds to a certain pattern. So, there would be a number for each block between 1 to n, so that it can describe the class number of the block.
5. After that, we can do vector quantization (VQ) technique on all *original* blocks which have the same class number. Note that there is a code book for each of the n classes of patterns.

6 Experimental Studies

6.1 VQ Results

In order to implement the VQ technique to be applied in face recognition, we have used a low pass filter (2D- Moving average with mask 9×9) on each of face image at the first step. The images were selected from the standard image databases, AR [51], MIT [52], and ORL [53]. It can remove the noises of image and is able to detect the components of the face. Then, we applied a code book with 128 code vectors. Next, we tested the code books of different sizes and we found that code book with size 128 is the optimal.

Finally, for each training image, we created a histogram based on the number of similar vectors of each code word. Figure 4 shows a sample histogram for a face image. As a result, we will have a histogram for each of the training images. In order to find the output image, the histogram of input image and existing images in the database have been compared and the closest histogram was found.

We implemented this method using Delphi language, on standard image databases such as ORL, AR, Yale using a PC system with CPU 2.19 GHz and 1.87 GB of Ram. We observed the recognition rate between 95% and 97% (depending on the size of used mask). In this experiment, Error Recognition Rate (ERR) has been measured to 2.6%.

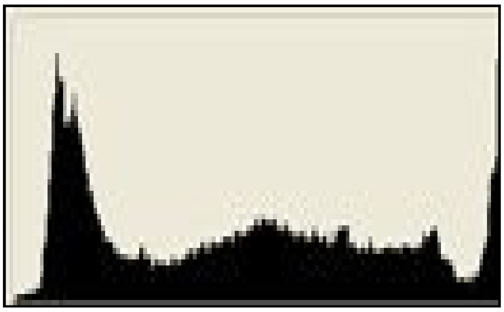

Fig. 4. A sample of face histogram obtained with the proposed approach

6.2 CVQ Results

Observing the results obtained from the implementation of CVQ technique demonstrates that it has much potential for face recognition at high accuracy. As mentioned before, VQ is a robust technique for face recognition, especially in real time systems. However, when the number of input vectors of images is increased, it is no longer beneficial. Nevertheless, CVQ classifies the vectors into some patterns and then VQ can be used for vectors of each class. Moreover, by using this technique, we can utilize the two unique characteristics in human face, geometric structure of the face, and skin correlations. Hence, recognition rate is improved in comparison with other existing face recognition methods. The proposed method was implemented and tested using MIT-CBCL, AR, Yale and ORL image databases. At the first step, the faces in images are cropped. Then a filter such as Sobel filter is applied on each cropped face image in order to detect edges in faces. This enables us to classify each block of the size $n \times n$ in each of predefined patterns. Finally, VQ technique is used for all the blocks of the same pattern. We have implemented this method using the Java language, on a system with CPU 2.4 GHz and 512 MB of Ram. The recognition rate has been observed to be between 93% and 100% (depending on the type of database). Table 1 shows the recognition rate in some major face recognition methods and that of our proposed approach with respect to MIT image database.

Table 1. Recognition rate of some face recognition method along with our proposed approach

Method	Percent of Recognition Rate
Global PZM	82.91
AWPPZMA	92.31
Eigen face(k=20)	55.56
Eigen face(k=60)	69.23
Eigen face(k=117)	76.07
Modular PCA(k=64)	76.06
Our method	93

The required time for pre-processing has been measured as 12 msec and for recognition it has been measured at most 25 msec. Therefore, the total time would be 37 msec. The reason why we could achieve small processing time is that the proposed algorithm avoids from complex calculations. This will consequently improve the overall performance of the recognition with higher accuracy. We achieved the recognition rate of 45.83 and 37 percent for YALE and AR database images. For YALE database, there are 24 image groups, each group for an individual person. In each group, we have selected 5 images for training. In AR image database, there are images of different people in the same position and state. We have selected one image for each of the 65 persons. Then, we selected another image of each person to test such that it would be the same for all persons.

7 Conclusions

In this paper, a new face recognition approach based on Classified Vector Quantization (CVQ) has been proposed. We extended the concept of this technique in order to classify components of face images into some patterns and then we used Vector Quantization in order to create a code book for each pattern. In Comparison with other methods, our algorithm can be implemented without using hard mathematical computations.

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