Facial Image Query System Based on Time Series for Pilgrims Identification

التحقق من الحجاج عن طريق الاستعلام بصور الوجه المبنية على السلاسل الزمنية

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الملخص

أثناء الحج، لا يحمل كثير من الحجاج بطاقات التعريف الخاصة بهم في معظم الوقت. ولذا، فإن التعرف على الحجاج مجهولي الهوية تعتبر واجباً مهماً لكثير من الجهات العاملة في الحج. ومن التقنيات المفيدة في هذا المجال تقنية التعرف على الأوجه آلياً. تقدم هذه الورقة خوارزمياً جديداً للتعرف على الأوجه وكيفية تطبيقه في مجالات الحج. يعتمد الخوارزم المقترح على فكرة استكشاف الأشكال المتكررة في السلاسل الزمنية. في البداية، يتم تحديد صورة الوجه واستخراجها باستخدام خوارزم "فيولا-جونز"، ثم يتم تحويل الصورة الناتجة إلى سلسلة زمنية من خلال الألوان الرئيسية الثلاثة للصورة الملونة. ويتم تطبيق هذه العملية على جميع الحجاج. وحيثما احتجنا لتعريف حاج مجهول الهوية، يتم تطبيق الخوارزم المقترح في هذه الورقة لاستكشاف الأشكال المتكررة للسلسلة الزمنية لصورة ذلك الحاج الملونة وتختبرها لإيجاد العلاقة مع السلاسل الزمنية المنتجة لجميع الحجاج. ونظراً لوجود ملايين الحجاج سنوياً، فإنه من الضروري تقصير طول هذه السلاسل الزمنية لتقليل زمن تنفيذ الخوارزم، وقد تم استخدام تقنية (DFT) لهذا الغرض. أخيراً، فقد تم تنفيذ النظام المقترح على واجهة سهلة الاستخدام.

Abstract

During Hajj, many pilgrims do not hold their own identification cards most of the time. Therefore, idintifying unknown pilgrims is an important role of many hajj authorities. One of the useful techniques used for this purpose is face recognition. This paper describes a new face recognition algorithm based on time series motif discovery and its application to pilgrims identification. At beginning, the face image is located and extracted using Viola-Jones algorithm, then the resulting facial image is converted into time series from the three primary colors of the colored face images. This process is done iteratively for all pilgrims. Whenever an unknown pilgrim is to be identified, motif discovery algorithm is used to mine the hidden motifs from the time series of the colored face image of that pilgrim and tested to find the relationship among these generated time series. Because there exist millions of pilgrims every year, these raw time series need to be reduced in their length to shorten the run-time. For this purpose, we used dimensionality reduction using Discrete Fourier Transformation(DFT). Finally the proposed system was implemented in a friendly user interface demo.

Introduction

Hajj has received a great attention by the government of Saudi Arabia as it is the land of revelation and it contains the Qibla to which all muslims pray five times daily. Every year, millions of muslims make their lifetime journy, where they come to Makkah to meet the inivtaion of Allah and perform the fifth pillar of Islam, Hajj. When they arrive to the lands of Saudi Arabia, they need the move from a plcae to another visiting the holy cities and sites. Most of the pigrims do not hold their own identification documets throughout these movements. There are many cases where some of these pilgrims need to be identified in order for hajj authorities to provide the best services for them. These applications include health care, guiding lost pilgrims, identifying authorized and unauthorized pilgrims, and many others.

There exist many techniques used for identifying people. Some of these techniques use electronic identification methods, such as RFID tags or barcodes 000. Other techniques use recognition methods, such as voice, face and meovement recognition 0.

The methodology adopted in this paper, is the facial recognition approach, where the photos of all authorized pilgrims are to be taken during application for Hajj. These photos *make the core base in our system. As one of the most successful applications of image analysis and understanding, face recognition has recently received significant attention, especially during the past few years. In addition, the problem of machine recognition of human faces continues to attract researchers from disciplines such as image processing, pattern recognition, neural networks, computer vision, computer graphics, and psychology. A general statement of the problem of machine recognition of faces can be formulated as follows: given still or video images of a scene, identify or verify one or more persons in the scene using a stored database of faces. Available collateral information such as race, age, gender, facial expression, or speech may be used in narrowing the search (enhancing recognition). The solution to the problem involves segmentation of faces (face detection) from cluttered scenes, feature extraction from the face regions, recognition, or verification (see Figure 1). In identification problems, the input to the system is an unknown face, and the system reports back the determined identity from a database of known individuals, whereas in verification problems, the system needs to confirm or reject the claimed identity of the input face.*

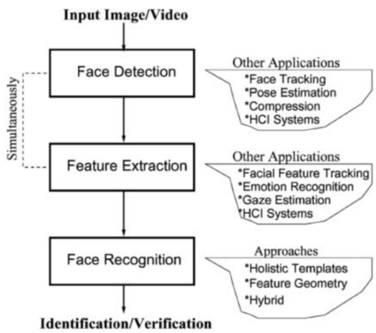

Figure 1: Configuration of a generic face recognition system.

In this paper, we focus mainly on content-based image retrieval (CBIR), which is shown in Figure 2. The problem is to search for in image in a large database of digital images 0. More formally, given a query image, get the ''closest'' image to the query image from the database.

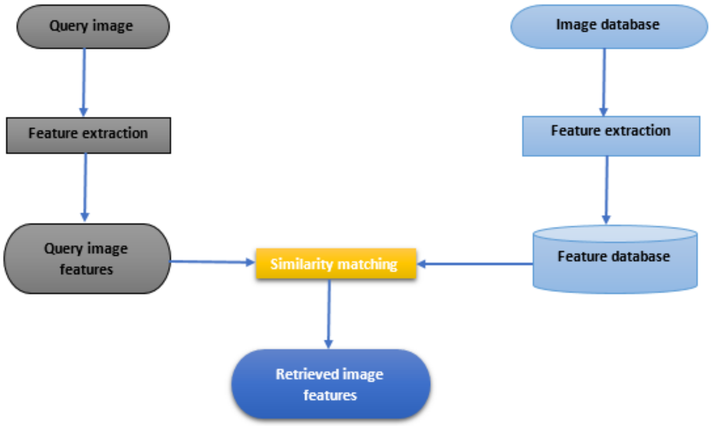

Figure 2: Content-based image retrieval (CBIR).

The method adopted in this paper is to get an image for all authorized pilgrims. These images are preprocessed, i.e., converted to time series based on RGB-color scheme, and then stored in a database. To identify a pilgrim, his/her photo is taken and converted to a time series. This time series is searched against the available database, i.e., mining the time series.

A time series database is an unordered set of n time series while the time series motif of a time series database is the unordered pair of time series, which is the most similar among all possible pairs.

The concept of time series motifs was first proposed in 2002 by J. Lin 0. At the same time, clear descriptions and definitions of the related concepts about time series motifs were given in details, such as k-motifs 0, the trivial match 0, and so on. Subsequently, more researchers are focusing on the study of time series motifs mining. In recent years, many sophisticated papers on the topic were published in top journals and conferences. Examples include Knowledge Discovery and Data Mining (KDD) journal 0, The Very Large Data Bases (VLDB) journal 0, IEEE International Conference on Data Mining (ICDM) 0, ...etc. Furthermore, research results have also been applied in medicine, environmental studies 0, biology 0, telemedicine 0, weather prediction 0 and other fields.

Time series motifs first appeared in the biomedical sequence analysis and were used to describe structural characteristics of biological sequences. Its significance lies in the fact that frequently occurring patterns are often able to reflect some important features of the *original sequences, such as the special structures of biological sequences, important words in the voice sequences and special behaviors of robot activities.*

In this paper, we will build a detection system to human facial images. This system uses Viola-Jones algorithm to extract facial area and convert it into a time series, which is in turn stored in a database for later use in recognition. For a query image, the same procedure will be applied and the resulting time series will be searched against the database to see whether it is stored in the database or not.

The paper is organized as follows. In Section 2, a general overview of the proposed system is presented. Time series of images is discussed in Section 3, and the experimental results are presented in Section 4. Finally, we conclude the paper in Section 5.

Proposed System

The detection system is composed of two parts as shown in Figure 3. The first part handles images to build an image database (or gallery). In the second part, the query image is treated and searchd against all DB images to get a decision of existing or not. In the following subsections, we will explain these stages in brief.

2.1. Building images database (images gallery)

Figure 3 (left) shows the process of building a time series database of the faces of interest. First, the frames of faces are extracted from the original photos. In order to extract the faces, we used the well-known Viola-Jones algorithm 0.

In the next step, RGB colors of the face is concatenated to get a unique vector or time series of the facial image of 768 in length. To process a million or more images, which is the case, one needs to care about storage and efficiency. Hence, a compression technique of the data is a must. There are various techniques for data compression, such as Discrete Fourier Transformation (DFT), Discrete Wavelet Transformation (DWT), and Piecewise Aggregate Approximation (PAA). For simplicty of implementation, DFT 0 is used in our system. The final setp is to store the compressed time series in a database.

2.2. Query image processing

For an image query, the same steps are applied as explained in the previous subsection to get its charactersitc time series. This time series is searched against all DB images to get a decision of existence. This process is shown in Figure 3 (right).

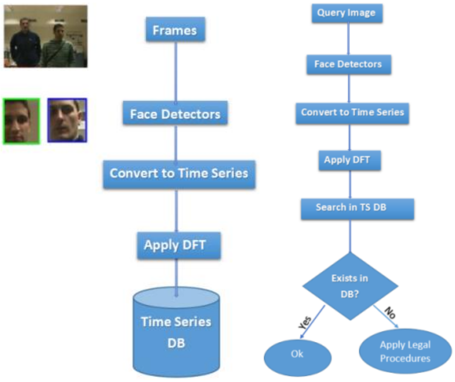

Figure 3. (left: extract faces, convert to time series, and store in DB. (right): query image process and search in DB.

Time series of an image

A time series is a sequence $X = (x_1, x_2, \cdots, x_m)$*, where* m *is the number of observations. Tracking the behavior of a specific phenomenon/data in time can produce important information. Time series can be very long, sometimes containing billions of observations 0. A time series motif is a set of subsequences (i.e. segments) of a time series, which are very similar to each other in their shapes. Figure 4 illustrates an example of a motif. The red and blue time series shown overlapped on one another are the motifs. The motifs are so similar such that it is implausible that they happened at random and therefore they deserve a further exploration.*

Motif discovery is a core subroutine in many research projects on activity discovery 00, with applications in elder care 0, surveillance, and sports training 0. In addition, there has been a recent explosion of interest in motifs from the graphics and animation communities, where motifs are used for finding transition sequences to allow just a few motion capture sequences to be stitched together in an endless cycle 0.

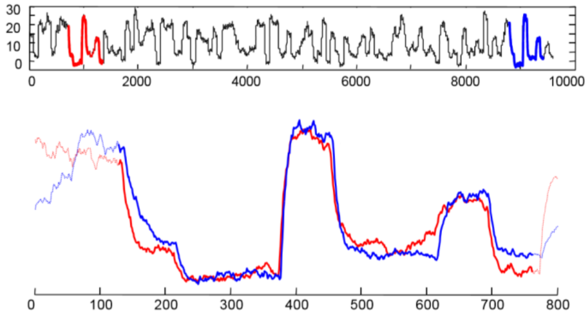

Figure 4. (top): A motif of length 640 beginning at locations 589 and 8,895. (bottom): by overlaying the two motifs we can see how remarkably similar they are to each other.

In this paper, the color contents of the image are utilized to generate face image time series. The image size is reduced to 32×32*. Then, RGB primary colors, of size 256, of the image are extracted and concatenated to form the time series of length 768. For millions of these time series, this length is of computional cost. Therefore, we need to reduce this length by using some comressionn techniques. In the following subsection, we explain the compression technique we used in our system. In subsection 3.2, the motif discovery algorithmis explained.*

Dimensionality reduction

The key aspect to achieve efficiency, when mining time series data, is to work with a data representation that is lighter than the raw data. This can be done by reducing the dimensionality of data, while maintaining its main properties. An important feature to be considered, when choosing a representation, is the lower bounding property.

By this property, given two raw representations of the time series T *and* S*, the following equation must be true:*

$$d_{feature}(R(T), R(S)) \leq d_{true}(T, S) \qquad (1)$$

where d_{true} *is a true distance measure for the raw data (such as the Euclidean distance), and* $d_{feature}$ *is the distance between two time series, in the reduced space,* $R(T)$ *and* $R(S)$.

If a dimensionality reduction technique ensures that the reduced representation of a time series satisfies such a property, we can assume that the similarity matching in the reduced *space maintains its meaning. Moreover, we can take advantage of indexing structures such as GEMINI 0 to perform speed-up search while avoiding false negative results.*

3.2. Motif discovery algorithm

In this subsection, we describe the motif discovery algorithm in detail which is based on the generated image time series. In this algorithm 0, which is shown in Figure 5, we extend the triangular inequality pruning method to preprocess the time series dataset and utilize an optimized matrix structure to improve the efficiency of this algorithm. First of all, we randomly select a time series T_1 *from time series dataset as the reference time series. Then, we calculate the Euclidean distances from other time series to* T_1*. After that, according to the Euclidean distances, we make the linear arrangement of these time series as shown in Figure 6.*

Figure 6 presents the differences of Euclidean distances between each pair of consecutive time series. In our algorithm, we use the notation $lower\_bound(C_i, C_j)\ (1 < i < j)$ *to denote the difference between* $D(C_1, C_j)$ *and* $D(C_1, C_i)$*. For example, based on the triangle inequality principle, the difference between both sides of the triangle must be smaller than the third side. So,* $lower\_bound\ (C_2, C_3)$ *must be smaller than the actual Euclidean distance between* C_2 *and* C_3*. If the* $lower\_bound\ (C_2, C_3)$ *is greater than the range* R*, we don't need to calculate the actual Euclidean distance. Certainly,* $C_2, C_4, C_5, and\ C_6$ *are not in the same motif, because the lower bounds from* C_2 *to other time series are greater than* R*. This is a very important point which needs to be emphasized. We extensively leverage the triangle inequality pruning method to make the preprocessing on the distances and realize the pruning quickly. Secondly, on the basis of the preprocessing on the distances between time series, we can construct the time series matrix. According to the symmetry of the Euclidean distance, the matrix* $C[\,][\,]$ *is a symmetric matrix. When most of element values in the matrix are 0,* $C[\,][\,]$ *is a sparse matrix. So, we use a compressed storage structure, which is the triple sequence table* Euc_dist*. At last, based on the previous operations, we implement our Motif Discovery*

Algorithm. In our Motif Discovery Algorithm, the triple sequence table Euc_dist *stores the values of row, column, and distance. The* $C\_count[\,]$ *stores the number of time series the distances of which to* C_i *are less than* R. *Then, we look for the element with the largest value in array* $C\_count[\,]$ *and add the time series.*

Algorithm 1 :Motif Discovery Algorithm

```
Initialize max ← 1
for i ← 2, m do
    if C_count[i] > C_count[max] then
        max ← i                                  ▷ get motif center
    end if
end for
motif_center ← C_max
add motif_center to motif
    ▷ find the time series in Euc_dist, the distance of each time series to C_max is less than R
for i ← 1, lengthofEuc_dist do
    if Euc_dist[i].row == max then
        k ← Euc_dist[i].col
        add C_k to motif
    end if
    if Euc_dist[i].col == max then
        k ← Euc_dist[i].row
        add C_k to motif
    end if
end for
return motif
```

Figure 5. Motif Discovery Algorithm

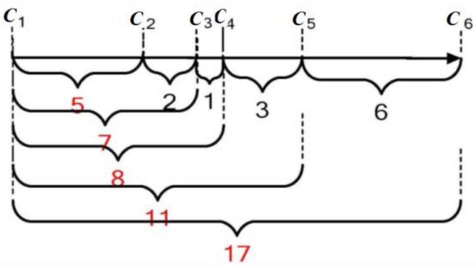

Figure 6. Linear arrangement of time series according to Euclidean distances.

Experimentation

In our experiments, the system is designed to retrieve or match a query image. In addition, it can also classify the images. In the following subsections, we explain the simulation program designed for experimenting the proposed system and the results of some cases.

Program design and implementation

To test the proposed system, we implemented the whole process in one program, run it, and test it. The motif discovery algorithm was coded using MatLab version 8.1.0.604 (R2013a), run on a computer with a 3.2 GHZ Intel I3 processor and 2 GB of RAM. The program interface is shown in Figure 7.

Figure 7. The interface of the program.

To verify the accuracy and efficiency of the method, two experiments have been conducted. The test data for these experiments is from the face recognition database of Essex University, UK 0, which contains color face images of 395 individuals; 20 images per indvidual. The total number of images is 7900. One gallery is provided in this database, which conyains high resolution pictures. In our experiments, 4 color face images of 20 subjects from this gallery were selected, every subject including 4 pictures. The color images in Essex University face recognition database have already been sampled to 32-by-32 pixels. First, based on color information, these selected pictures are converted into time series. Second, DFT algorithm is used to reduce the 768-dimensions. The conversion result of one subject is shown in Figure 8.

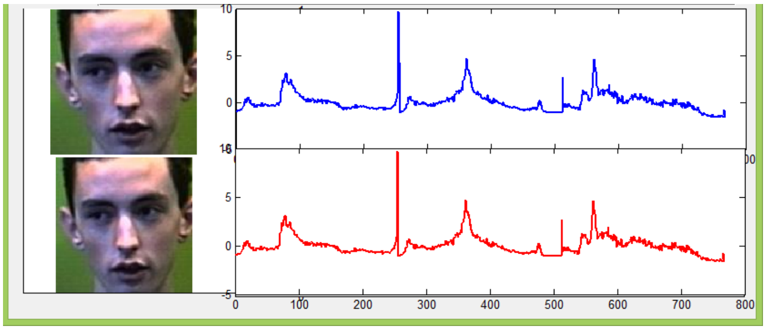

Figure 8. Conversion of an image to time series.

Retrieval

The subjects (or individuals) were split into two groups where images of every subject are of different positions in oreder to have varities for query. Then, we run the Motif Dicovery algoritm for the following cases:

Case 1

query an image from the gallery against all gallery images: in this case, the query image was chosen from the stored image DB (or gallery) and queried against the whole set of images available in the gallery to the find the exact image. The result of this case is shown in Figure 9.

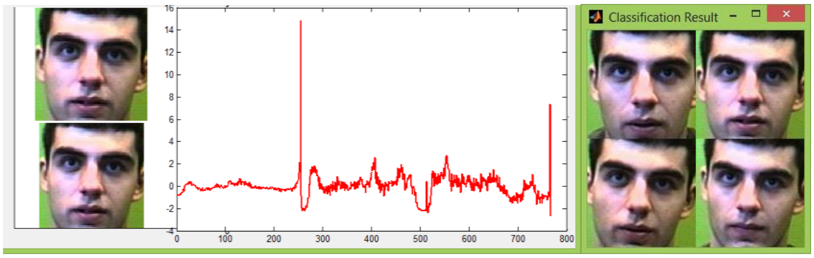

Figure 9. Retrieval of image fom the gallery with its similars.

Case 2

query an image not in the gallery against all gallery images: in this case, the query image does not belong to the image gallery and queried against the other images in the gallery to find the nearest image. The result of this case is shown in Figure 10.

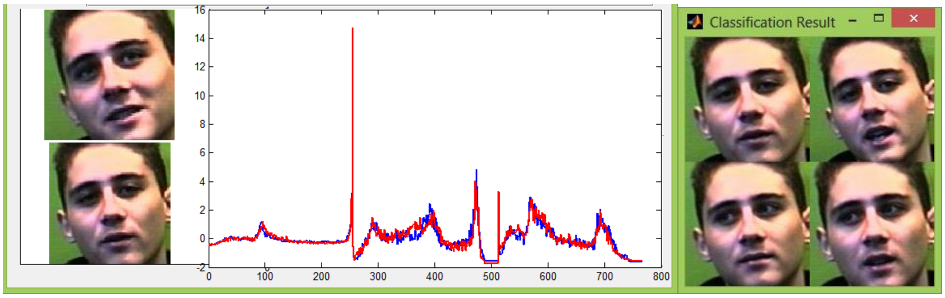

Figure 10. Retrieval of image fom the query images with its similars.

Case 3

Twin case: to distingush between twins is not an easy task. While DNA tests may fail to make a distinction between identical twins, face recognition may be able to find some differences due to environmental changes 00. Here, we give an example of very similar twins, (with a correllation coefficient = 0.89246%) whose photos and time series are shown in Figure 11 (left and middle). We tested our system for this case to check wether our algorithm is able to retrieve the exact image of that twin or not. The results of our experiments proved that our proposed system is accurate enough to distinguish between two very similar twins, where the image of one of them was queried against both twin images and then we got the correct matching results. This is shown in Figure 11 (right).

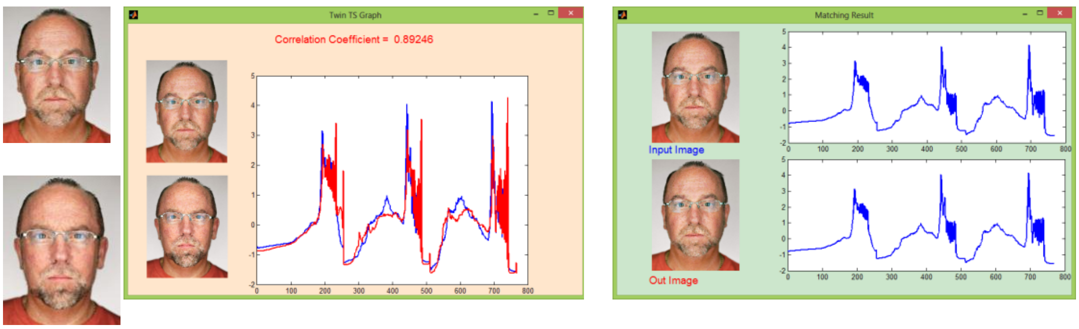

Figure 11. (left): Twin images, (middle): time series representation,(right): matching results.

Conclusion

In this paper, the well-known problem of recognition and matching of human faces has been addressed using the most recent methodology and techniques. The proposed system is *composed of two stages. In the first stage, the whole images are preprocessed to have only the facial parts, which are converted into time series and their dimensionality are reduced using DFT and the results are stored in a database system. In the second stage, the query image is treated in a similar fashion and is searched against the time series database to check for its existence in the database. The method is proved to be very efficient and accurate. We propose to use this proposed method for building an identification systems for pilgrims during hajj.*

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