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Face Matrix: A Quick Search and Indexing Method for Suspect Recognition in Police Departments

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Abstract: This study presents an indexing and a quick sort method that could be used to find the possible matching guilty pictures from the police database by using a tracing software and eyewitness descriptions about the suspected guilty profile. It is well known that databases located in the police departments have a large amount of prerecorded convicted guilty pictures. Searching a picture from database for recognition is very hard and it may take too much time. In addition to this, it can also require to track many redundant pictures to find the correct guilty. There is, of course, no guarantee that Photofit (robot picture) is included in database. Therefore police departments have difficult problems to recognize exact guilty using Photofits described by eyewitness. In this paper, a matrix construction using particular distances on face has been demonstrated. In order to find these certain points on the face, a new point selection schema and some existing recognition methods are presented. Finally, three different determinant values of this matrix are computed and are used for picture indexing in the database. In the test environment, the system results 30 different matches with the predefined Photofits by using this indexing algorithm together with a face tracing software and a patch program, proving that the tracking time for redundant pictures is reduced.

Key words: Image indexing, image retrieving, image search, face images, suspect recognition

INTRODUCTION

Almost every police station and department use face tracing systems and robot pictures gathered from the eyewitness descriptions given, in order to identify the suspects in Turkey as well as in other countries (Isik, 2002; Jarvis, 2006). Although photofits are very useful to recognize the suspects, it is very difficult to match them with real pictures. Since finding and catching the real suspect quickly is one of the main tasks of police force, the face recognition of suspect is a crucial operation. For this reason, drawing and tracing Photofits by using eyewitness descriptions and matching them with the pictures of the real guilty persons who had criminal records in the past, should be done immediately. Since some offences may not committed by old guilty persons, Photofits may not match with prerecorded pictures, but still usage of this method is very useful especially in ordinary crime events.

Basic sequence of picture matching progress in police departments is as follows;

- After crime scene investigation, eyewitness/s is/are invited to police department.
- A face painter tries to create the suspect's physical profile while the eyewitness is describing the physical characteristics of the suspect.
- A face figure, which is agreed with the eyewitness, is exposed on the screen.
- This face is matched with preloaded pictures in the database using any face recognition method.
- If any picture agreed with the eyewitness, matched with the Photofit, the suspect is identified and then the picture is distributed to all police patrols.

Despite this procedure may seem simple, it requires too much attention and eats too much time. In past, eyewitness had been trying to identify guilty persons' pictures using photo albums, but databases have been used approximately for 20 years.

Although computer databases help in reducing the time there is still a great number of pictures to be examined and it is a well known truth that people have not kept their concentration for a long time. Hence methods should be developed to reduce the number of pictures to be surveyed by the eyewitness. The method should ideally deliver only a few promising pictures from which the eyewitness would identify the suspect.

Another problem is that record fetching takes too much time when many police stations are trying to access

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the image database concurrently (Liaw *et al*., 2006; Smith and Chen, 2000; Rui and Huang, 2000). This problem is not specific to the face recognition, but it is a challenge of the database management theory. Present proposed method helps decreasing the seek time for the appropriate records.

Although people use significant features to identify each other and this is one of the main cognitive abilities of the human beings, the scientific research on facial recognition is almost a new research area. The idea of identifying an object in terms of the properties that make it different from everything else is old. With the upcoming of electronic data processing or in simple words computing, the identification of persons became an interesting area and with the growing facilities and the speed of computers this area became a popular research field. All study in this area is covered by the term biometrics. Although it is an interesting and huge area, we will focus on face recognition in this research.

Of all the biometric techniques, facial recognition is perhaps the most fascinating in concept, so it is not surprising that there are many related works in the context of facial recognition. The range starts with introductory works like Liaws and friends' work or Hansch's work and goes over techniques and methods (Hansch, 2006; Stewart-Bartlet *et al*., 2002; Wiskott *et al*., 1997; Moghaddam and Pentland, 2000; Brunelli and Poggio, 1997, 1993, 1992), up to special usage areas and other related topics of the face recognition like (Gutta and Wechler, 1998; Feldkamp, 2006; Tsapatsoulis *et al*., 2001; Gagalowicz and Roussel, 2005; Krishna *et al*., 2006). Biometrics systems are not only interesting for cognitive research, but they also are important for security and social structures since there are many real applications in this field. These tests are generally sponsored and supported by government institutions. More, other works can be found in BSI (2006a-d).

The first category of studies above normally covers the history and overview of facial recognition. The second category of these works deals with the different techniques and methods of face recognition. Face recognition techniques can be subdivided into two different categories; feature-based approaches and holistic approaches. To solve the problem in feature-based approaches, the knowledge of people is used for face recognition. Brunelli and Poggio (1993) and Baur (2006) introduce two different methods in this category; geometric and template-based approaches (1997). Another example for this category is introduced by Wiskott *et al*. (1997). The method is based on the idea of fitting the face into a grid of nodes and edges. The nodes are called fiducial points and located on specific points like the tip of nose or middle of the pupils. Such distinctive points are also used for constructing the face matrix described in later sections.

The holistic approaches are field independent. Since the face recognition can be seen as a subset of object recognition, algorithms used for object recognition can be also adopted to face recognition. In this case it doesn't matter if we are dealing with faces or e.g., cars or buildings. The input pictures can be described as vectors of gray level values. An image of a resolution of x*y pixels would than construct a matrix of the size of x*y. This matrix can be shown as a vector, i.e., as a concatenation of all rows and the affinity of two images can simply be calculated as the Euclidian distance of these vectors.

Daniel assumes that 16 facial parameters are enough for the recognition. The empirical tests have showed that 16 significant points are enough for a good recognition result. To compare different facial images Daniel normalizes the pictures as follows (Hansch, 2006).

$$y_i = \frac{x_i - m_i}{\sigma_i}, i = 1,2,...,16$$
$$m_i = E[x_i], \sigma_i^2 = E[(x_i - m_i)^2] \quad (1)$$

In the method we described here, it is not necessary to normalize the facial image. We assume that the images in the database have all the same resolution and do not need to be normalized because of the usage of Photofit. The method of calculating the relevant measures and constructing the required matrix is described in detail in the next section.

The main focus of this study lies on the image retrieval from databases. One of the basic problems of face recognition is the demand for real time applications and speed. Image retrieval as a term is generally used to define algorithms which retrieve proper images from the image database as a result of a given query. According to Feldkamp (2006) we can subdivide those algorithms in two categories: algorithms using textual meta information about images which are stored with the images and those who refer directly to the contents of an image. In the first category we can find e.g., a database which holds pictures of actors and textual information about the actors. A query in such a database can be the name of an actor retrieving the picture of the actor. This kind of retrieval is more a textual retrieval and is not the subject of this work. Although our system stores the data about the matrix in a textual form, it can be seen in the second category. It doesn't matter that the describing information about an image is stored in textual form. The stored information is the content of the image and so the retrieval is content-based image retrieval. The content-based image retrieval has three abstraction levels: In the first level only the primitive attributes like color, textures, forms etc. are considered (Feldkamp, 2006). These attributes can be found without help or additional information. In the

second level there are also derived attributes which require additional information like human and machine cooperation. In the third abstraction level are attributes which require high level information about the objects. Feldkamp complains that there are only a few algorithms concerning the third level. The system described in this study can be placed between the second and the third level. Ideally the system retrieves only one images according due the query. But if there are more than one possible match the system will retrieve a set of possible Photofits so the human knowledge is required.

FACE MATRIX

Proposed method represents a face matrix that could be used for further image indexing and convenient fetching technique. Figure 1 shows the face matrix that includes two correction matrixes marked by I_1 and I_2, respectively. Main purpose of the matrix is to find a single value (Δ_T), which will be used for indexing, using determinant calculation. Here, ϵ refers an acceptance ratio and it is used to create a little interval for matching similar faces and I_1, I_2 are used to calculate Δ_{I1} and Δ_{I2} and those determinants will be used to ensure coherency of Δ_T.

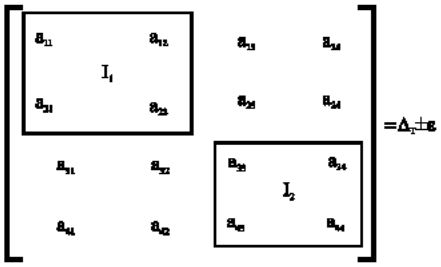

Fig. 1: Face matrix

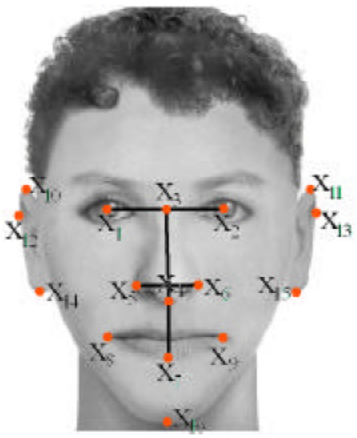

Fig. 2: Sample Photofit and predefined points

Elements of the matrix are gathered from distances between predefined points on Photofits. Present suggestion for points' selection that will be used as elements of the matrix is shown in Fig. 2 which demonstrates an example Photofit with important predefined points and distances. The elements are calculated by simple formula;

$$a_{ij} = \left|x_p - x_q\right| \tag{2}$$

First of all, Δ_T must be unique as much as possible for each face. In order to ensure coherency of Δ_T, I_1 and I_2 marked in matrix are constructed using the most important distances from the Photofit because I_1 and I_2must include most discriminative distances of a face. In addition both Δ_{I1} and Δ_{I2} will also play an important role for searching in future. When a match is found using Δ_T, then extra controls will be made using Δ_{I1} and Δ_{I2}, for this reason selection of p and q is critical while a_{ij} is being calculated. Sample calculation of a_{ij} can be seen below;

$$\text{For } I_1 : a_{11} = \left|x_2 - x_1\right|, a_{12} = \left|x_3 - x_4\right|,$$
$$a_{11} = a_{21} = \left|x_5 - x_6\right|, a_{22} = \left|x_4 - x_7\right|$$

$$\text{For } I_2 : a_{33} = \left|x_8 - x_9\right|, a_{34} = \left|x_8 - x_{16}\right|,$$
$$a_{43} = \left|x_9 - x_{16}\right|, a_{44} = \left|x_7 - x_{16}\right|$$

Here the most discriminative points are assumed as $[x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{16}]$.Since matrix is constructed by elements, any discriminative values (calculated from points or areas) can be used for elements so of course many other methods can be applied to calculate a_{ij}, for example point selection method in Hansch's study can be implemented (Hansch, 2006).

After the matrix constructed then three different determinants are calculated and these all determinants added in a single variable showed below,

$$\Delta_T = \Delta\text{-}\Delta_{I1}+\Delta_{12}\Delta_T\pm\varepsilon \tag{3}$$

and finally Δ_T is used for indexing and Δ_T-ε and Δ_T+ε interval is used for searching.

SUSPECT RECOGNITION SYSTEM

We offer a Suspect Recognition System (SRS) that could be used for police depart-ments in order to find suspect physical profile within the criminal records. The system, in fact, is very simple and it can be implemented cheaply but its application may take a little bit much time. Main schema of suggested system can be found in Fig. 3.

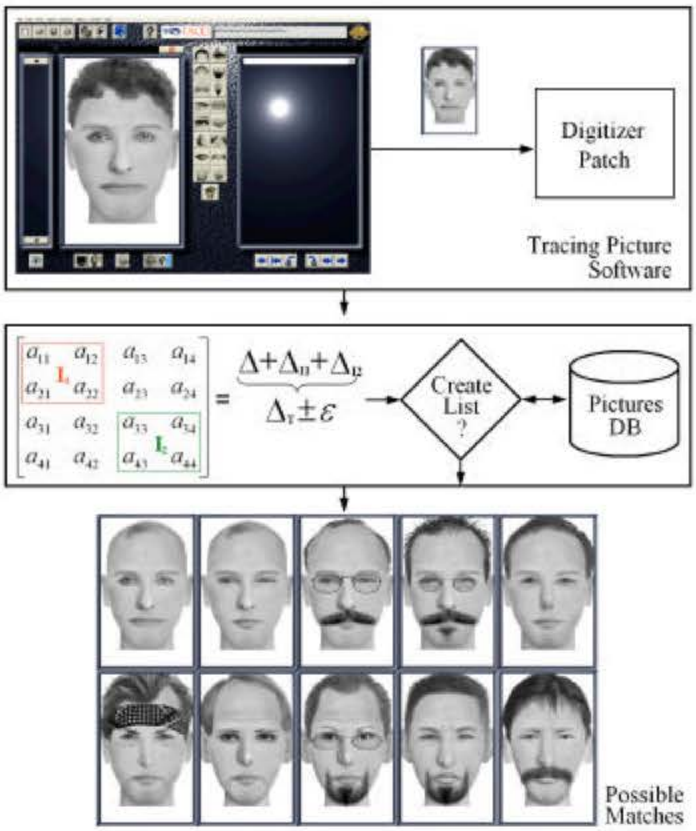

Fig. 3: Suggested suspect recognition system for police departments

This system consists of a face designer software, a digitizer patch that is used to get further matrix elements, a matrix builder and database search function patch and finally guilty pictures which match with Photofit related to given accept ratio parameter.

Initially, just after the system installation finished three additional attributes, which are Δ_T._Δ_{I1} and Δ_{I2}, must be added to picture table in image database and all previous guilty pictures located in database must be processed by digitizer patch procedure, finally Δ_T._Δ_{I1} and Δ_{I2} values calculated by patch procedure are recorded to related attributes on individual picture tuples. In addition, if face tracing software is not suitable to hold face attributes curtain points, which are used for calculation of distances between attributes, another table must be created in database for recording point locations on face (pixel coordinates or metric values measured from left tab position can be used for these points) for all individual face attributes and all point values must be recorded that table. After these all preliminary works are completed, the system is ready to be executed.

Suspect recognition sequence starts with determination of eyewitness descriptions. While eyewitness is explaining suspect specifications, a face painter is continue to select correct face shapes (attributes) and changes the face with particular organs. When all specifications are completed and eyewitness and painter are agreed on suspect's Photofit then searching process is ready to begin. After completion of Photofit, using predefined points on that Photfit, which are already recorded in database, a matrix is constructed and Δ_T._Δ_{I1} and Δ_{I2} are calculated. Next, first of all database is searched for Δ_T -ε and Δ_T +ε_interval and then all the tuples found are controlled using Δ_{I1} and Δ_{I2} Finally matching guilty pictures collected in a list. Then, eyewitness looks at list and tries to find correct guilty, if the list does not include correct one then this whole process might be done again using different face organs.

The most important benefit of using of the matrix method is that, any accessory or attribute for certain suspect (such as glasses, mustache, beard, hair style, etc.) have no effect in recognition.

CONCLUSIONS

Finding the real guilty person has vital importance for justice. Consequently, recognition of guilty physical profile is important as well. For this purpose, face

recognition processes have been used to expose the suspects profile in many police departments for years. Some software used for face recognition have some problems. Since many police departments require to use the common database concurrently, searching time increases and some other accessories also cause that the correct profile could not be found in the database. The proposed system supports to reduce the seek time by using a single value searching. At the same time, the system also provides a list to show possible matches. Therefore, eyewitness has a chance to select the correct one among some different profiles. This situation supports recognition consistency. In real applications, some different pictures which are not matched (different) with Photofit, can be added into the list to support eyewitness's differentiation. Any further works can be applied to the proposed system, so that, a new point selection method or an enlarged matrix size can be used to increase the coherency and uniqueness. Moreover, this system can be applied in national customs services to restrict entrance of the guilty people and as a prevention method against terrorists.

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