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LNCS 11771

Software Technology: Methods and Tools

51st International Conference, TOOLS 2019
Innopolis, Russia, October 15–17, 2019
Proceedings

Springer

Lecture Notes in Computer Science 11771

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ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-030-29851-7 ISBN 978-3-030-29852-4 (eBook)
https://doi.org/10.1007/978-3-030-29852-4

LNCS Sublibrary: SL2 – Programming and Software Engineering

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Preface

Started in 1989, the TOOLS conference series has played a major role in the development of object technology and has contributed in making it popular, mainstream, and ubiquitous. The 50th edition of the series "The Triumph of Objects," was held in Prague in 2012 and was meant to be the closing edition for a conference that had brought, to a large audience, ideas originally shared only by a niche. After an interruption of seven years, TOOLS now starts again with a scope extended to software technologies and applications and all the modern approaches to software engineering, robotics, and machine learning.

The edition 50th+1 was held at Innopolis University, the educational center of the techno-city of Tatarstan, Russia. The numbering (50+1) is to emphasize the reopening of the series and celebrate it. The venue, being one of the most recently established universities in the world (2012), seemed to be the right place to celebrate a synergy between tradition and future. This volume contains the papers presented at TOOLS 50 +1 during the period October 15–17, 2019. There were 62 submissions. Each submission was reviewed by at least three Program Committee members. The committee decided to accept 32 papers, including long and short contributions. The program also includes four invited talks.

The conference was made possible by the joint effort of several colleagues and departments. We would like to thank Bertrand Meyer and Alexandr Tormasov in their role as general chairs, as well as Inna Baskakova, Oksana Zhirosh, Sergey Masyagin, Giancarlo Succi, Alberto Sillitti, Andrey Sadovykh, Mansur Khazeev, and Alexandr Naumchev for supporting the creation and organization of the event. JooYoung Lee, Adil Adelshin, and Sophie Ebersold were instrumental in promoting the conference in Russia and abroad. Last but not least the Program Committee that operated effectively in defining the program (a full list of names of additional reviewers is included in this volume). The process of volume preparation was enabled and simplified by a fundamental tool like EasyChair. Financially, we have also received the support of Eiffel Software, SOFTEAM, and Springer, which funded the Best Paper Awards.

July 2019

Manuel Mazzara
Jean-Michel Bruel
Bertrand Meyer
Alexander Petrenko

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Applying Face Recognition in Video Surveillance Security Systems

Bauyrzhan Omarov[1], Batyrkhan Omarov[2,3](✉), Shirinkyz Shekerbekova[4], Farida Gusmanova[1], Nurzhamal Oshanova[4], Alua Sarbasova[1], Zhanna Yessengaliyeva[1], Agyn Bedelbayev[1], Akmarzhan Maikhanova[1], Nurzhan Omarov[5], and Daniyar Sultan[1]

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Abstract. Face Detection and Recognition is an important surveillance problem to provide citizens' security. Nowadays, many citizen service areas as airports, railways, security services are starting to use face detection and recognition services because of their practicality and reliability. In our research, we explored face recognition algorithms and described facial recognition process applying Fisherface face recognition algorithm. This process is theoretically justified and tested with real-world outdoor video. The experimental results demonstrate practically applying of face detection from several foreshortenings and recognition results. The given system can be used in building a smart city as a smart city application, also in different organization to ensure security of people.

Keywords: Smart city · Video surveillance · Face recognition · Face detection

1 Introduction

If we talk about the concept of "smart city", first and foremost, it is improving the quality of life and creating comfortable living conditions for citizens. This is the combination of various technologies, management of communications, infrastructure, in the near future IOT.

The goal is the optimal use of modern technologies in each of the spheres of city life for more rational use of resources and improving the quality of life, doing business, etc. So, "Safe City" is the most important component of the "smart city" concept, besides video surveillance as part of a safe city, the state is becoming "the eyes" of a smart city.

Smart cities often intersect with a digital city, a wireless city, a safe city, an eco-city, a city with low carbon monoxide emissions, architectural perfection and other regional development concepts. This should be confused with the concepts of the

© Springer Nature Switzerland AG 2019
M. Mazzara et al. (Eds.): TOOLS 2019, LNCS 11771, pp. 271–280, 2019.
https://doi.org/10.1007/978-3-030-29852-4_22

industry of information technologies, electronic document management, electronic reporting, intellectual transport and an intelligent urban water/gas/power supply network. Smart City is sharing data over the Internet, cloud services, geospatial infrastructure, dedicated telecommunication channels and other new generations of information technology. CCTV cameras, included in open or protected monitoring and control systems, ensure broadband cross-border interaction of all municipal structures, and facilitate the intellectual integration of applications into user innovations, open innovations, public innovations, and joint innovations. The process of transition to a smart city is characterized by a steady interest of both local enterprises and foreign investors. In this process, there are no templates for the use of video surveillance and network technologies. The main thing is an intelligent and cost-effective result. In addition, of course, there are increased requirements to the processing of video data streams, the quality of video surveillance equipment.

2 Literature Review

There are several approaches to create a face recognition algorithm.

The empirical approach was used at the very beginning of the development of computer vision. It is based on some of the rules that a person uses to detect a face. For example, the forehead is usually brighter than the central part of the face, which, in turn, is uniform in brightness and color. Another important feature is the presence of parts of the face in the image - the nose, mouth, eyes. To determine the faces, we did a significant reduction of the image area, where the presence of a face was assumed, or perpendicular histograms are constructed. These methods are easy to implement, but they are practically unsuitable in the presence of a large number of foreign objects in the background, several persons in the frame or when changing the angle.

The following approach uses invariant features characteristic of a face image. At its core, as in the previous method, lies the empiricist, that is, the attempt of the system to "think" as a person. The method reveals the characteristic parts of the face, its boundary, change in shape, contrast, etc., combines all these signs and verifies. This method can be used even when turning the head, but with the presence of other faces or a heterogeneous background, recognition becomes impossible.

The following algorithm is the detection of faces using patterns that are specified by the developer. A person appears to be a kind of template or standard, the purpose of the algorithm is to check each segment for the presence of this pattern, and the check can be made for different angles and scales. Such a system requires many time-consuming calculations.

All modern facial recognition technologies use systems that learn through test images. For training, bases with images containing faces and not containing faces are used. Each fragment of the investigated image is characterized as a feature vector, with which the classifiers (algorithms for determining an object in a frame) determine whether this part of the image is a face or not.

Currently, several dozens of computer methods for face recognition are actively used: methods based on neural networks [1]; the main components (own persons) [2, 3, 4]; based on linear discriminant analysis [5, 6]; elastic graph method [7]; a method based on hidden Markov models [8–12]; method based on flexible contour models of the face; method of comparison of standards; optical flux method; methods based on lines of the same intensity; algebraic moments; Karunen-Loeve decomposition; fuzzy logic; Gabor filters, etc. A good overview of these methods can be found in [13].

One of the first developed methods of facial recognition is the method of main components (own faces). Its distinguishing feature is that the main components carry information about the signs of a certain generalized face. Face recognition using linear discriminant analysis is based on the assumption of linear separability of classes (persons) in image space. Neural network methods have a good generalizing ability.

3 Facial Recognition Problem

Recognition of objects is an easy task for people, the experiments conducted in [14] showed that even children aged one to three days are able to distinguish between remembered faces. Since a person sees the world not as a set of separate parts, our brain must somehow combine various sources of information into useful patterns. The task of automatic face recognition is to isolate these significant features from an image, transforming them into a useful presentation and producing some kind of classification.

The process of face recognition, which is based on geometrical features of the face, is probably the most intuitive approach to the problem of face recognition [14, 15]. Experiments on a large data set have shown that, alone, geometric features cannot provide enough information for face recognition.

In this work, we explore face detection and recognition process, describe their mathematical representation and do experiments with facial recognition using Fisher-face algorithm.

3.1 Development Overview

The solution as proposed in this research work consists of two parts as recovering low resolution image and the identity of object using the recovered high resolution image.

Image restoration part consists of three subtasks as

1. Converting the low resolution image to digital form
2. Image enhancement and recovery
3. Converting to graphical image from digits.

3.2 Face Detection

At the first stage, the face is detected and localized in the image. At the recognition stage, the image of the face is aligned (geometric and luminance), the calculation of the signs and the direct recognition - the comparison of the calculated signs with the standards embedded in the database. The main difference of all the algorithms presented will be the calculation of signs and the comparison of their aggregates among themselves. Such face detection system types shown in Fig. 1.

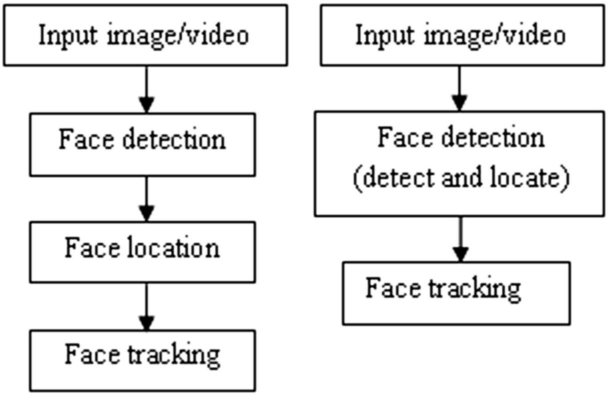

Fig. 1. Face detection architecture.

3.3 Face Recognition

There are several different face recognition algorithms as correlation, eigenfaces, linear subspaces and fisherfaces. There were several experiments on identification the effectiveness of those algorithms where the FisherFaces algorithm was chosen as the best one with the lowest error rate in human face recognition. In accordance with experiment results made before we decided to choose the FisherFaces algorithm for face identification and recognition processes due to its fast and guaranteed recognition of the human. Figure 2 shows the plot that illustrates the error rate depending on the number of principal components.

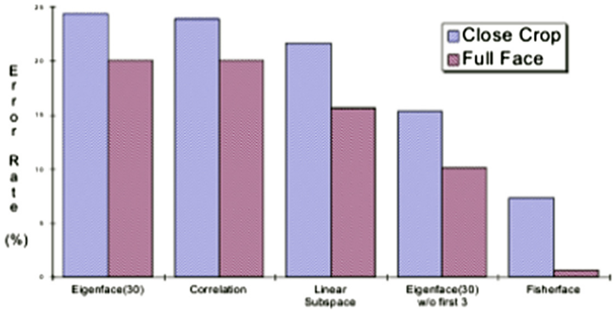

Fig. 2. Face detection architecture.

As can be seen from the above graph, the FisherFace method learns the set of projections which perform well over a range of lighting variation, facial expression and even presence of glasses. Below, we explain the algorithmic description of the Fisherfaces method:

Let there be a random vector with samples drawn from classes: $X = \{X_1, X_2, \ldots, X_n\}$

$$X_i = \{X_1, X_2, \ldots, X_n\} \tag{1}$$

The scatter matrices S_B and S_{W} are calculated as:

$$S_b = \sum_{i=1}^{c} N_i(\mu_i - \mu)(\mu_i - \mu)^T \tag{2}$$

$\sum_{i=1}^{c} \sum_{x_i \in X_i} (x_i - \mu_i)(x_j - \mu_j)^T$, where μ is the total mean:

$$\mu = \frac{1}{N} \sum_{i=1}^{N} x_i \tag{3}$$

And μ_i is the mean of class $i \in \{1, \ldots, c\}$:

$$\mu_i = \frac{1}{|x_i|} \sum\nolimits_{x_j \in X_j} x_j \tag{4}$$

Fisher's classic algorithm now looks for a projection that maximizes the class separability criterion:

$$W_{opt} = \arg\max\nolimits_W \frac{|W^T S_B W|}{|W^T S_W W|} \tag{5}$$

Following the method of Belhumer, Hespanha and Kriegman, a solution for this optimization problem is given by solving the General Eigenvalue Problem:

$$S_W^{-1} S_B v_i = \lambda_i v_i \tag{6}$$

There's one problem left to solve: The rank of S_W is at most (N-c), with N samples and classes. In pattern recognition problems the number of samples N is almost always smaller than the dimension of the input data (the number of pixels), so the scatter matrix S_W becomes singular. In [BHK97] this was solved by performing a Principal Component Analysis on the data and projecting the samples into the (N-c)-dimensional space. A Linear Discriminate Analysis was then performed on the reduced data, because S_W isn't singular anymore. The optimization problem can then be rewritten as:

$$W_{fld} = \arg\max\nolimits_W \frac{\left| W^T W_{pca}^T S_B W_{pca} W \right|}{\left| W^T W_{pca}^T S_W W_{pca} W \right|} \tag{7}$$

The transformation matrix that projects a sample into the (c-1) dimensional space is then given by:

$$W = W_{fld}^T W_{pca}^T \tag{8}$$

Face detection, recognition and gender classification experiments carried out on the basis of facial images database [16]. Sample images are shown in Fig. 3. In the formation of the database size of the images and the shooting conditions were the same. They used a 24-bit JPEG format. The base [16] contains pictures of people, male and female, of different nationalities and ages. It reflects changes in a person's appearance: different hairstyles, beards and glasses presence. In preparation for the experiment, two training samples have been created. The first of them contains five images of each person (only 5 × 395 = 1975 images). Second, 10 images of each person's individual learning (10 × 395 = 3950 images). In addition, the dataset has several datasets as Face94, Face95, Face96, and Grimace that the characteristics are listed, below.

Fig. 3. Sample images of faces.

The approach that is used in this method finds out the facial features to discriminate between the persons. The performance of the system that uses the FisherFaces algorithm is highly depends on the input data. The FisherFaces provides a total reconstruction of the projected image by normalizing processing of the image [5, 17–19]. The total set of procedures is given in the Fig. 4.

As can be seen from the Fig. 4, the process of face verification starts with the detection stage, where the image is taken from the camera and is considered as an input data. Then, there goes the normalization process in order to construct the proper image that can be used in FisherFace algorithm. Face normalization actually consists of geometry normalization, background removal and lighting normalization. The images of the face are normalized to a fixed size. If the face was in a wrong angle this angle is determined then is corrected in accordance with rules.

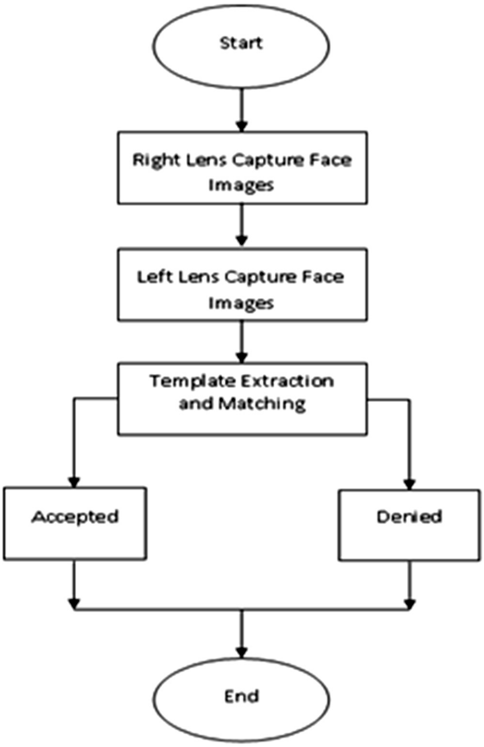

Fig. 4. Face detection architecture.

4 Facial Recognition Problem

Face recognition system generally involves two main stages as “Face Detection” and “Face Identification”. First one is face detection, where the system is searching for any faces then takes the image of this face. Following this, image processing cleans up the facial image into black-white colors. In our research, face can be detected from several foreshortenings. Implemented results are given in Fig. 5.

Fig. 5. Face detection from several foreshortenings.

After detecting face, next step will be executed. In this step, feature extraction and verification process will be done. After recognizing the detected and processed facial image is compared to a database of faces in order to decide who that person is, Fig. 6.

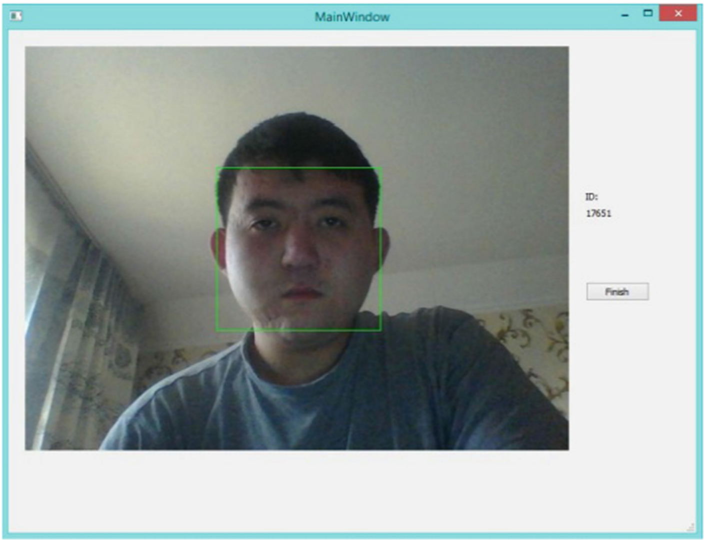

Fig. 6. Face recognition. Identification of personal id

5 Conclusion

In this work, we applied Fisherface face recognition algorithm for facial recognition problem as a video surveillance system of Smart City application. We used Fisherface algorithm because of its practicality and high recognition rate. The mathematical representation of facial recognition problem and Fisherface algorithm was investigated. Experiment results demonstrate face detection and recognition results. Further, we are going to use the proposed system as an application of a Smart City Platform and for schools to identify pupils by faces.

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