Journal of Theoretical and Applied Information Technology
15th May 2019. Vol.97. No 9

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

FACE RECOGNITION IN VIDEO SURVEILLANCE SYSTEMS AS AN APPLICATION OF SMART CITIES

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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.

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.

1.1 Smart City

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 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, facilitate the intellectual integration of applications into user innovations, open innovations, public innovations, 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. And here, of course, there are increased requirements to the processing of video data streams, the quality of video surveillance equipment.

Modern cities, especially megacities, in recent years have become sources of increased risk for their citizens and visitors. These are not ceasing acts of a terrorist nature, rampant criminal passions, traffic tensions and constant accidents on city roads, offenses at railway facilities and airports, threats to critical infrastructure of cities. We need new

Journal of Theoretical and Applied Information Technology
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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

approaches, new solutions. First of all, the intellectualization of security systems.

The security and livelihood systems of today, developed by our tandem, are distinguished by a multi-format, open architecture that allows you to respond very flexibly to the demands of security professionals, to take into account many factors that distinguish a modern city. Developed IP solutions made it possible to provide live remote monitoring of objects from anywhere in the world. Concern about protecting the security systems themselves led to such mandatory attributes as fail-safe archiving with redundancy, support for cryptographic algorithms.

1.2 Recognition Systems in Smart City

The newest video analytical automation systems for urban video surveillance systems should include the following minimum cycle: detection - recognition - classification - response - investigation - documentation. Moreover, the delays between the stages of this essentially unified process should be minimal — minutes, in rare cases — hours. That's when confidence and security will come to our cities. And in the townspeople there will be peace and understanding that the authorities are not only concerned, but they are doing everything to make people confident in their future.

Recognition system is a hardware-software complex for automatic verification or identification of a person using a digital image. The task of face recognition is solved when creating access control systems, automated passport control systems, when conducting operational search activities, etc. [1].

In the process of face recognition, a number of difficulties arise associated with the influence of lighting conditions, head rotation, and age-related changes on recognition results.

The following main stages of the verification and identification process [2] are distinguished: registration and normalization of the image; feature selection; calculating the measure of proximity / difference; building a decision rule.

2. LITERATURE REVIEW

2.1 Face Recognition in Videostream of the Urban Video Security System

The rapid development of information technology has led to an increase in computing power, an increase in the volume of data being processed, a general “connectivity”, and an improvement in hardware. These improvements allowed us to optimize many processes in various areas of human life, including those related to information security. Increasingly, the use of the Internet of things in the lives of ordinary citizens can be found, and the embodiment of the “smart” city system is also becoming a reality. One of the most important tasks of the “smart” city system is to increase the security of all urban processes. One of the possible ways to improve the security of urban processes is monitoring and analyzing the data of video streams received from the cameras of the urban video surveillance system.

Within the concept of the Internet of Things (Internet of Things, IoT), one of the most popular directions of development is the concept of a “smart city” (Smart City) [3]. A “smart” city is the provision of modern quality of life through the use of innovative technologies that provide for the economical and environmentally friendly use of urban life-support systems [4]. Thus, the concept of “smart” city includes energy efficiency, “smart” health care, “smart” education, “smart” transport, infrastructure, security, green planet (ecology), communications, including remote access to all types of services and services, “ smart city infrastructure, the introduction of ICT solutions to ensure public and information security, the Internet of Things, the development of wireless communication technologies. The concept of IoT is based on the ubiquity of the Internet, mobile technologies and social media [5].

The task of recognizing faces in a video stream, including in the context of an urban video surveillance system, is related to computer vision tasks. Computer vision allows you to recognize and analyze objects both on static images and in a continuous video stream. The task of face recognition consists of two stages: the stage of face detection, and then its recognition [6]. In order to recognize faces in a video stream, it is possible to use the computer vision API, which allows you to analyze video in almost real time. To do this, you need to extract frames from the video and send these frames to any API calls. Thus, in order to implement an application designed to automate the implementation of permanent monitoring of the video stream, for example, for urban video surveillance systems, it was decided to use the computer vision API from Microsoft Cognitive Service [7-8]. Microsoft Cognitive Services allows you to create "smart" applications that can see, that is, identify, describe and a bat images using image processing algorithms. This service includes many APIs that allow you to perform certain tasks, for

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

example, the Face API recognizes faces in an image, their age and gender, can correlate images and determine the likelihood that two different images represent the face of one person, and can also group images by visual similarity [9].

The application was developed in Microsoft Visual Studio Professional 2015 in C # using Microsoft namespaces. ProjectOxford.Face and Microsoft.ProjectOxford.Face.Contract, allowing to work with video streams as well. At this stage of the study, “surrogate” video streams were studied with good coverage of all participants and mainly with frontal faces. In this regard, the percentage of false recognitions was 0. In the process of recognizing subjects in a video stream, the task was also to additionally recognize the gender and age of an object. The percentage of incorrect recognition of sex is 4, incorrect recognition of age - 75%. In the near future, it is planned to conduct “field” studies in a real organization, for example, within the framework of the access control system. It is possible that the percentage of false positives will increase and additional adjustments or the choice of another method of face recognition will be required [10-11].

Recognizing faces in a video stream is an urgent task, since it can be useful for monitoring the crowd and searching for potential violators, for carrying out search and rescue operations, for counteracting intrusions into protected areas, for authenticating users in the context of payment systems and access control systems. Currently, many different applications and systems for these functions have already been implemented, but the task of face recognition still requires careful study, finding new approaches, as well as improving existing algorithms.

2.2 Face Recognition Approaches

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, a significant reduction of the image area is made, where the presence of a face is 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, and 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 a lot of 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 [12-13]; the main components (own persons) [14-16], based on linear discriminant analysis [6-7]; elastic graph method [17]; a method based on hidden Markov models [18-22]; 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 [23].

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 [15] 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 [24-25]. 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 Fisherface 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 Figure 1.

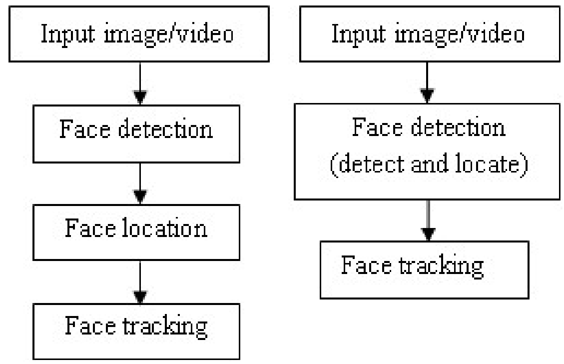

Figure 1: Face detection architecture.

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 it was decided to choose the FisherFaces algorithm for face identification and recognition processes due to its fast and guaranteed recognition of the human. Below we present some information about each of the mentioned methods.

One of the simplest approaches is the correlation method that is the nearest neighbor classifier. According to this approach, an image in the test set is recognized by assigning to it the label of the closest point in the learning set, where distances are measured in the image space. In case of image normalization the procedure is equivalent to choosing the image in the learning set that best fits to the test image. As this approach is considered as the simplest one there can appear several drawbacks such as lighting condition which means that there needs to be a special normalization process in accordance with lighting conditions. Secondly, this type of face checking is computationally expensive. Then, it requires large amount of storage units in order to contain numerous images of one person.

The Eigenfaces algorithm is concentrated on dimensionality reduction in computer vision by using Principal Component Analysis (PCA). The PCA used in Eigenfaces facial recognition method has some drawbacks. The PCA finds a linear combination of features that maximizes the total variance in data. It means that some discriminative information may be lost when throwing components away. For instance, let it be some variance in external source such light. The system that uses the

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15th May 2019. Vol.97. No 9

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

PCA do not necessarily contain any discriminative information at all, so the projected images are smeared together and there is no any classification in images.

The third approach is the Linear Subspaces that recognizes that a face is a Lambertian surface. It means that all images of the face lie in a 3D linear subspace of higher-dimension image space, regardless of lighting conditions. With three images of a face under three known and linearly independent lighting sources we can discover the albedo and surface normal of each point on face that allows us to reconstruct the original images under different lighting conditions (Figure 2). As well as other methods this method also has some drawbacks such as there can appear some face variability due to self-shadowing, pivot points and facial expressions. Moreover, this method is computationally expensive and memory intensive.

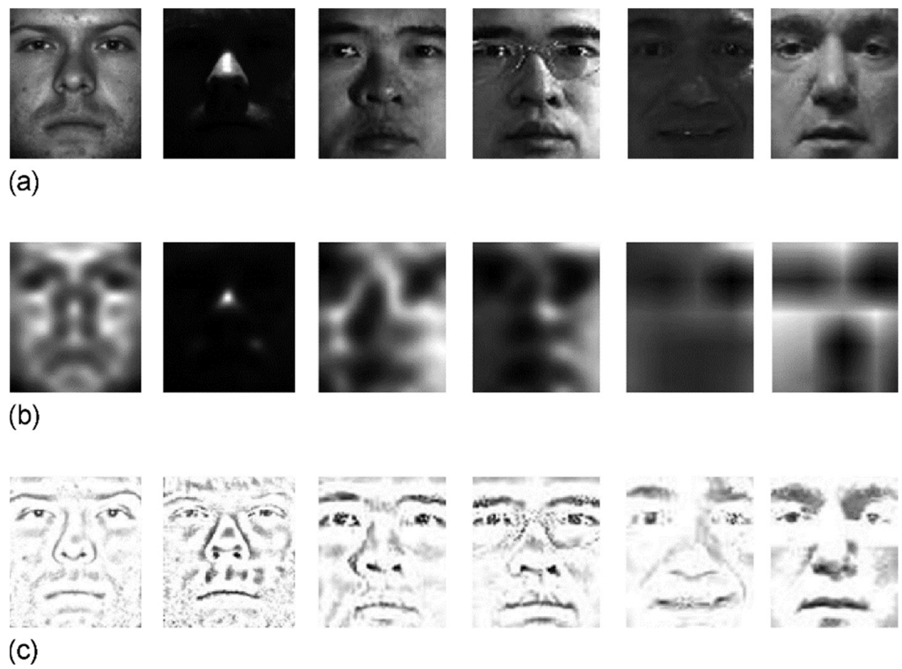

Figure 2: Different subsets of lighting

The last but not the least important face recognition method is fisherfaces algorithm that uses the same technique in regards to the Lambertian surfaces. FisherFaces algorithm is based on Linear Discriminant Analysis that performs the following idea of allocating the same classes together and the classes that are different far away from each other. It is faster than Linear Subspaces and uses less memory. Also, it is more accurate than Correlation and Eigenfaces.

Meanwhile, next test concentrated on different facial expressions of the person (Figure 3). It was tested full heads shots and closely cropped faces. Most of the time faces are taken with glasses, ambient light, three point lights from different angles and five different facial expressions.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 3: Lighting and Facial Expressions

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 4 shows the plot that illustrates the error rate depending on the number of principal components.

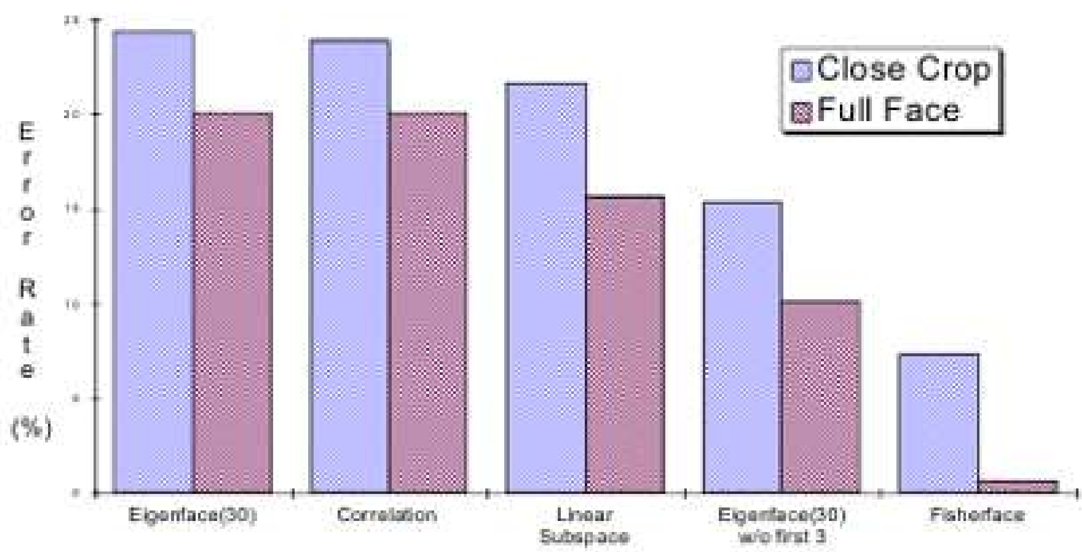

Figure 4: Comparative Analysis of Face Recognition Algorithms

In [26], the authors compare different face recognition algorithms for face detection and recognition. Figure 5 and Figure 6 illustrate training and prediction times of facial recognition by applying different face recognition algorithms [26]. As illustrated in figures, Fisherfaces face recognition algorithm has lowest training time (Figure 5) and lowest predicting time (Figure 6) that is very important to apply in ptz and street cameras of cities.

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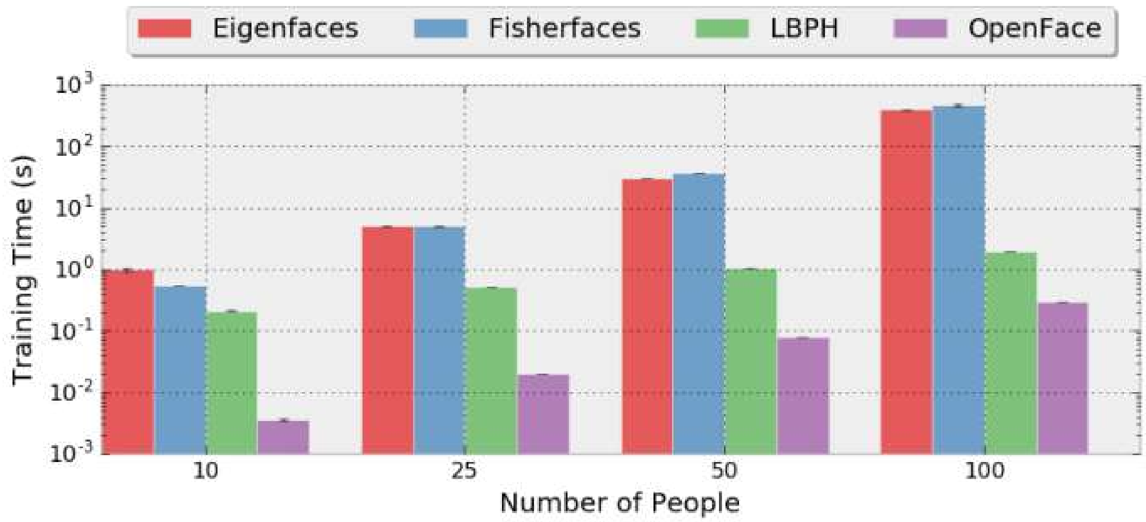

Figure 5: Comparison of training time of different face recognition algorithms

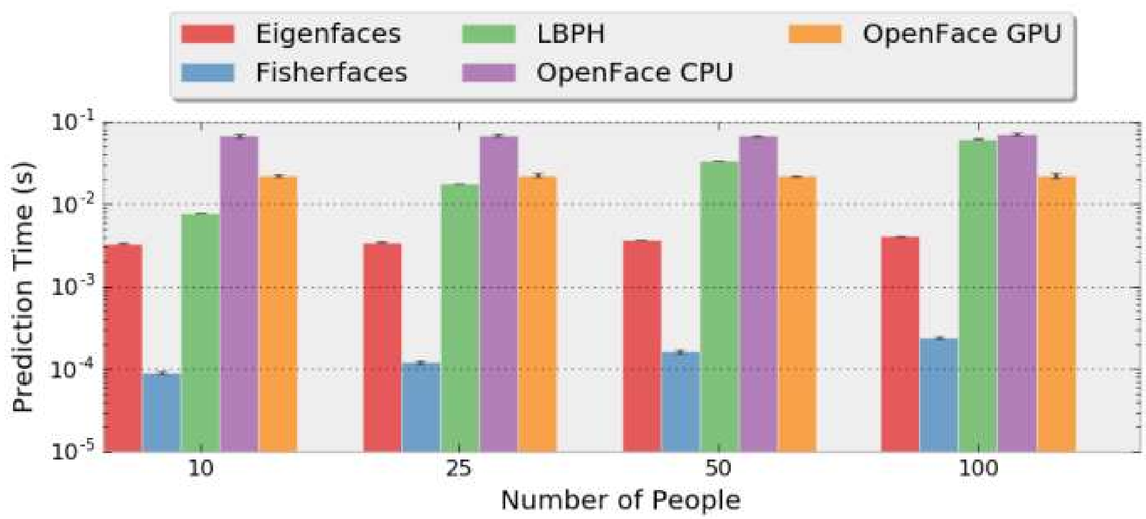

Figure 6: Comparison of predicting time of different face recognition algorithms

As can be seen from the above graphs, the FisherFace method learns the set of projections which perform well over a range of lighting variation, facial expression and even presence of glasses. The algorithmic description of the fisherfaces method is given below:

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

$$X_i = \{X_1, X_2, ..., X_n\} \quad (1)$$

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

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

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

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (3)$$

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

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

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

$$W_{opt} = \arg\max_W \frac{|W^T S_B W|}{|W^T S_W W|} \qquad (5)$$

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

$$S_W^{-1} S_B v_i = \lambda_i v_i \qquad (6)$$

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:

$$W_{fld} = \arg\max_W \frac{|W^T W_{pca}^T S_B W_{pca} W|}{|W^T W_{pca}^T S_W W_{pca} W|} \qquad (7)$$

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

$$W = W_{fld}^T W_{pca}^T \qquad (8)$$

Face detection, recognition and gender classification experiments carried out on the basis of facial images database [27]. Sample images are shown in Figure 7. 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 [27] 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 were created. The first of them contains 5 images of each person (only 5 × 395 = 1975 images). Second, 10 images of each person's individual learning (a total of 10 × 395 = 3950 images). Also, the dataset has several datasets as Face94, Face95, Face96, and Grimace that the characteristics are listed below.

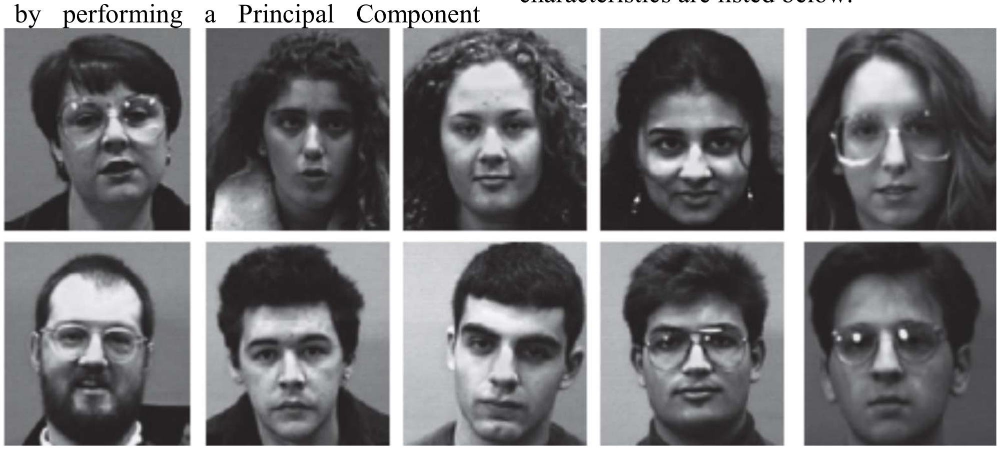

Figure 7: Sample images of faces

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 [29-31]. The total set of procedures is given in the Figure 8.

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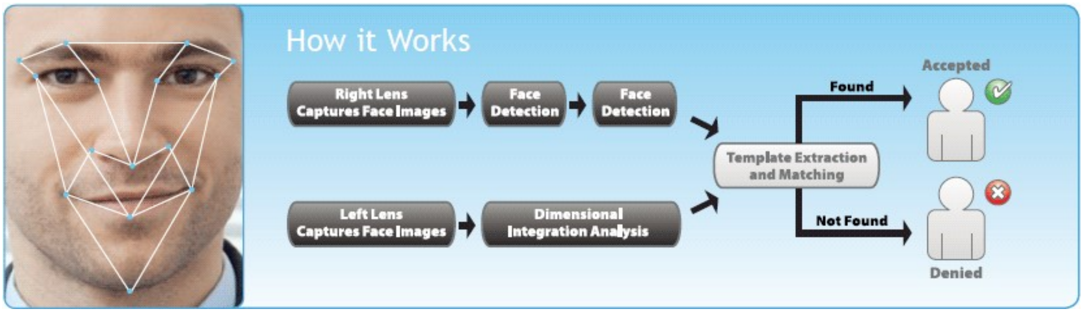

Figure 8: Face verification system in accordance with FisherFace algorithm

As can be seen from the Figure 8, 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.

3.4 Methodology

For pattern recognition, classic neural networks were used. As a learning algorithm, the algorithm for back propagation of errors was chosen [32-34].

The neural network is a classic multilayered full-connected perceptron. The sigmoid is chosen as the function of neuron activation as in formula (9):

$$f(x) = \frac{1}{e^{-cx} + 1}. \tag{9}$$

The number of hidden neurons was chosen to be 1024. The task of network training was solved for each individual subject. For each subject, half of the images were used to train the network, and the remaining half was used for testing. The input of the neural network was the image. The input of each neuron of the input layer was one pixel. The brightness value of each pixel was represented as a real number from the range [0; 1].

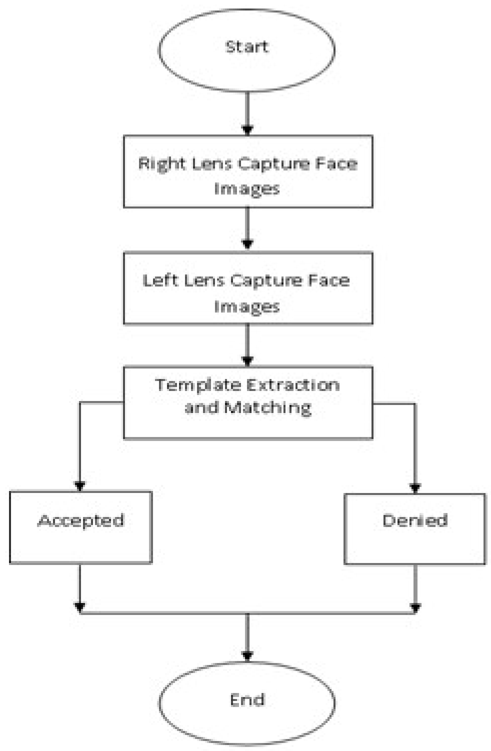

Figure 9: Face detection architecture

The output of the neural network is a variable that takes values from the range [0; 1]. In the event that the output value exceeded 0.85, the conclusion was made that the image submitted to the input was accepted, and if the output value was less than 0.15, it was rejected.

Face recognition system generally involves two main stages as "Face Detection" (Figure 9) 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

Journal of Theoretical and Applied Information Technology
15th May 2019. Vol.97. No 9

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

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 Figure 10.

Figure 10: Face detection from different 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, Figure 11.

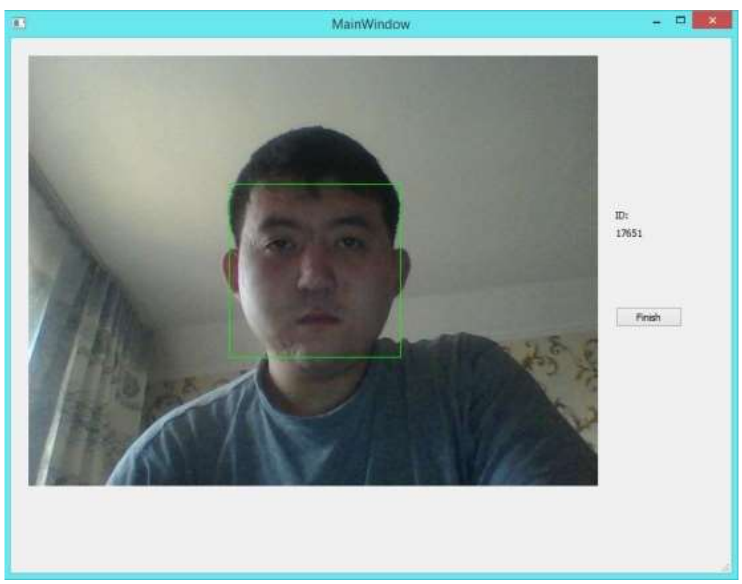

Figure 11: Face recognition.

4. CONCLSION

In this work we applied Fisherface face recognition algorithm for facial recognition problem as a video surveillance system of Smart City application. Fisherface algorithm was chosen because of its practicality and high recognition rate. The mathematical representation of facial recognition problem and Fisherface algorithm were investigated. Experiment results demonstrate face

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

detection and recognition results. Further, we are going to use the proposed system as an application of a Smart City Platform.

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