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DESIGN OF A FACE RECOGNITION SYSTEM

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ABSTRACT

A face recognition system is one of the biometric information processes, its applicability is easier and working range is larger than others, i.e.; fingerprint, iris scanning, signature, etc. A face recognition system is designed, implemented and tested at Atılım University, Mechatronics Engineering Department. The system uses a combination of techniques in two topics; face detection and recognition. The face detection is performed on live acquired images without any application field in mind. Processes utilized in the system are white balance correction, skin like region segmentation, facial feature extraction and face image extraction on a face candidate. Then a face classification method that uses FeedForward Neural Network is integrated in the system. The system is tested with a database generated in the laboratory with 26 people. The tested system has acceptable performance to recognize faces within intended limits. System is also capable of detecting and recognizing multiple faces in live acquired images.

1. INTRODUCTION

Face recognition systems are part of facial image processing applications and their significance as a research area are increasing recently. They use biometric information of humans and are applicable easily instead of fingerprint, iris, signature etc., because these types of biometrics are not much suitable for non-collaborative people. Face recognition systems are usually applied and preferred for people and security cameras in metropolitan life. These systems can be used for crime prevention, video surveillance, person verification, and similar security activities.

Face recognition system is a complex image-processing problem in real world applications with complex effects of illumination, occlusion, and imaging condition on the live images. It is a combination of face detection and recognition techniques in image analyzes. Detection application is used to find position of the faces in a given image. Recognition algorithm is used to classify given images with known structured properties, which are used commonly in most of the computer vision applications. Recognition applications use standard images, and detection algorithms detect the faces and extract face images which include eyes, eyebrows, nose, and mouth. That makes the algorithm more complicated than single detection or recognition algorithm. The first step for face recognition system is to acquire an image from a camera. Second step is face detection from the acquired image. As a third step, face recognition that takes the face images from output of detection part. Final step is person identity as a result of recognition part. An illustration of the steps for the face recognition system is given in Figure 1.

Acquiring images to computer from camera and computational medium (environment) via frame grabber is the first step in face recognition system applications. The input image, in the form of digital data, is sent to face detection algorithm part of a software for extracting each face in the image. Many methods are available for detecting faces in the images in the literature [1 – 9]. Available methods could be classified into two main groups as; knowledge-based [1 – 4] and appearance-based [5 – 9] methods. Briefly, knowledge-based methods are derived from human knowledge for features that makes a face. Appearance-based methods are derived from training and/or learning methods to find faces.

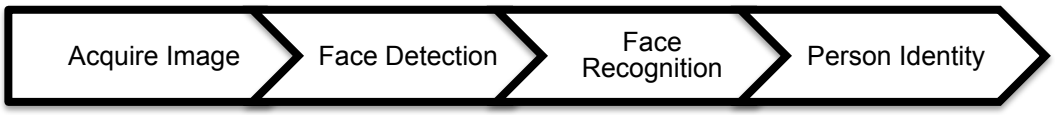


Figure 1 Steps of Face Recognition System Applications

After faces are detected, the faces should be recognized to identify the persons in the face images. In the literature, most of the methods used images from an available face library, which is made of standard images [10 – 17]. After faces are detected, standard images should be created with some methods. While the standard images are created, the faces could be sent to recognition algorithm. In the literature, methods can be divided into two groups as 2D and 3D based methods. In 2D methods, 2D images are used as input and some learning/training methods are used to classify the identification of people [1 – 15]. In 3D methods, the three-dimensional data of face are used as an input for recognition. Different approaches are used for

recognition, i.e. using corresponding point measure, average half face, and 3D geometric measure [16, 17]. Details about the methods will be explained in the next section.

Methods for face detection and recognition systems can be affected by pose, presence or absence of structural components, facial expression, occlusion, image orientation, imaging conditions, and time delay (for recognition). Available applications developed by researchers can usually handle one or two effects only, therefore they have limited capabilities with focus on some well-structured application. A robust face recognition system is difficult to develop which works under all conditions with a wide scope of effect.

2. DESIGN OF A FACE RECOGNITION SYSTEM

A throughout survey has revealed that various methods and combination of these methods can be applied in development of a new face recognition system. Among the many possible approaches, we have decided to use a combination of knowledge-based methods for face detection part and neural network approach for face recognition part. The main reason in this selection is their smooth applicability and reliability issues. Our face recognition system approach is given in Figure 2.

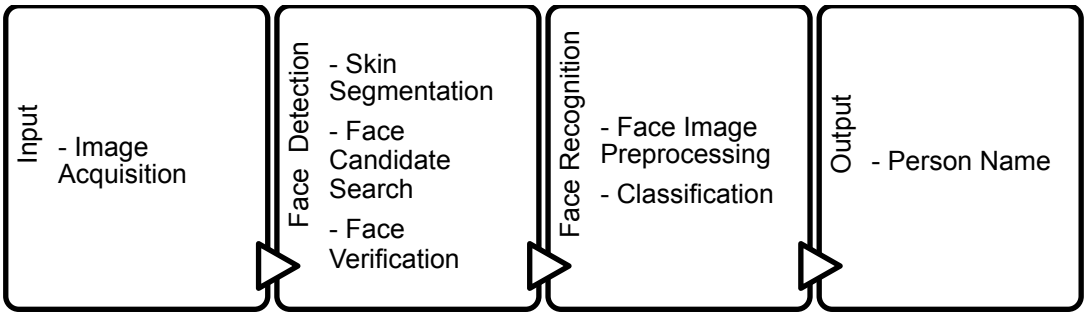


Figure 2 Face Recognition Approach

2.1. Input Part

Input part is prerequisite for face recognition system. Image acquisition operation is performed in this part. Live captured images are converted to digital data for performing image-processing computations. These captured images are sent to face detection algorithm.

2.2. Face Detection Part

Face detection performs locating and extracting face image operations for face recognition system. Face detection part algorithm is given in Figure 3.

Our experiments reveal that skin segmentation, as a first step for face detection, reduces computational time for searching whole image. While segmentation is applied, only segmented region is searched weather the segment includes any face or not.

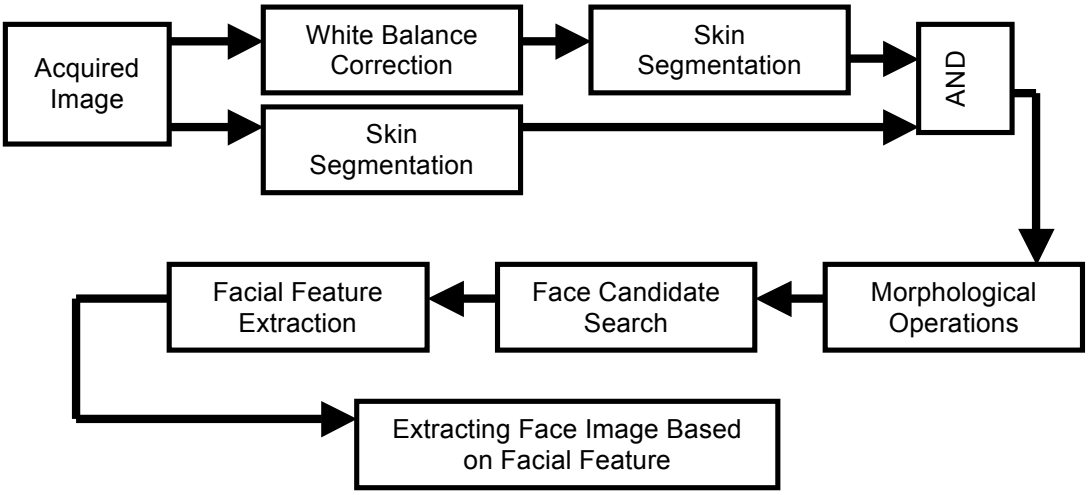
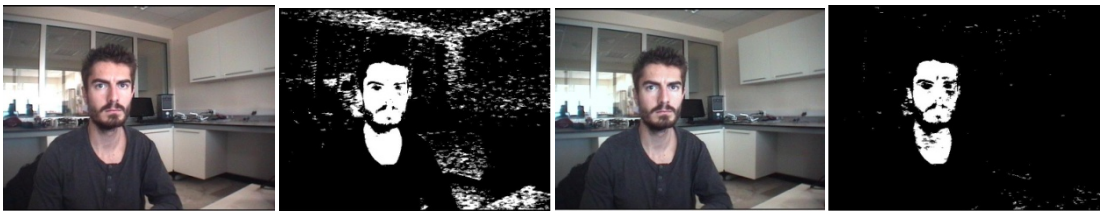


Figure 3 Algorithm of Face Detection Part

For this reason, skin segmentation is applied as a first step of detection part. RGB color space is used to describe skin like color [4].

White balance of images differs due to change in lighting conditions of the environment while acquiring image. This situation creates non-skin objects that belong to skin objects. Therefore, white balance of the acquired image should be corrected before segmenting it [18]. Results of segmentation on original image and white balance corrected image is given in Figure 4 and 5.



a.) *b.)* *c.)* *d.)*

Figure 4 Example of taken/white balance corrected image and skin color segmentation (a.) Original Image (OI), b.)Segmentation on OI, c.)White Balance Correction on OI (WBI), d.) Segmentation on WBI)

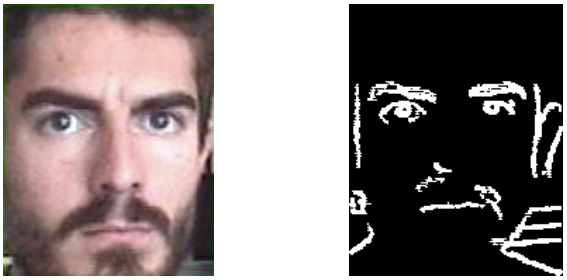
After “and operation” is applied on segmented images, some morphological operations are applied on final skin image to search face candidate. Noisy like small regions elimination, closing

operations are performed. Then, face candidates are choosen with two conditions which are ratio of bounding box of candidate and covering some gaps inside the candidate region. Ratio of bounding box should lie between 0.3 and 1.5.

Figure 5 Results of Segmentation on Uncorrected (Left) and Corrected Image (Right)

Based on these conditions, face candidates are extracted from input image with modified bounding box from original bounding box. The height of bounding box modified as 1.28 times bigger than width of bounding box because chest and neck parts will be eliminated if candidate includes them This modification value have been determined experimentally. These face candidates will be sent to facial feature extraction part to validate the candidates.

Final verification of candidate and face image extraction, facial feature extraction process is applied. Facial feature is one of the most significant features of face. Facial features are eyebrows, eyes, mouth, nose, nose tip, cheek, etc. The property is used to extract the eyes and mouth which, two eyes and mouth generate isosceles triangle, and distance between eye to eye and mid point of eyes distance to mouth is equal [2]. Laplacian of Gaussian (LoG) filter and some other filtering operations are perfomed to extract facial feature of face candidate [19].



a.) Face Candidate Image *b.) Face Image After Filtering*

Figure 6 Result of filtering operations on face candidate

Figure 6 shows that, facial features can be selected easily. After obtaining filtered image, labeling operation is applied to determine which labels are possible to be facial features.

After face cover corner points are calculated, face image can be extracted. Facial feature extraction, covering and face image extraction are given in Figure 7.

Figure 7 Facial Feature Extractions (Left) and Face Image (Right) for the author

Up to here, face detection part is completed, and face images are found in the acquired images. This algorithm is implemented using MATLAB and tested for more than hundred images. This algorithm detects not only one face but also more than one face. Small amount of oriented face are acceptable. Results are satisfactory for all purpose.

2.3. Face Recognition Part

Modified face image which is obtained in the Face recognition system, should to be classified to identify the person in the database. Face recognition part is composed of preprocessing face image, vectorizing image matrix, database generation, and then classification. The classification is achieved by using FeedForward Neural Network (FFNN) [13]. Face recognition part algorithm is given in Figure 8.

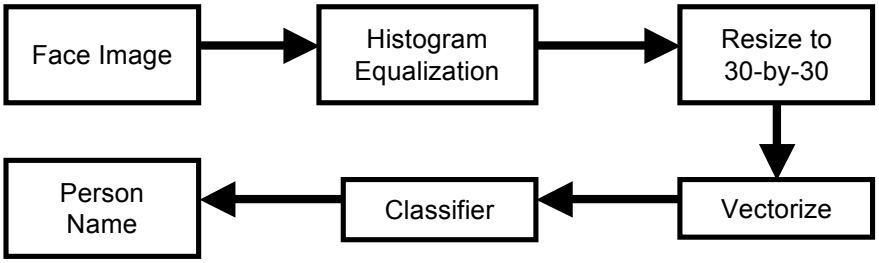


Figure 8 Algorithm of Face Recognition Part

Before classifying the face image, it should be preprocessed. Preprocessing operations are histogram equalizing of grayscale face image, resizing to 30-by-30 pixels, and finally vectorizing the matrix image.

In classifier, FeedForward Neural Network (FFNN) is used [19]. FFNN is the simplest structure in the neural network. This type of network structure is generally used for pattern recognition applications. System network properties are: input layer has 900 inputs, hidden layer has 41 neurons and output layer has 26 neurons. Output layer has 26 neuron since the number of people in database is 26.

After structure is generated, then network should be trained to classify the given images with respect to face database. Therefore, face database is created before any tests. A database is created for 26 people with 4 samples for each person. This results 104 training sample. Due to that, 900-by-104 size matrix will be training matrix. Training matrix vector element is arranged with four groups due to the number of samples for each person. Though, first 26 vector element belongs to first samples of 26 people, and it continues. Training matrix's columns are made from preprocessing image and then vectorizing to face image which generate database.

After training matrix and target matrix is created, then training of NN can be performed. Back propagation is used to train the network. Training performance and goal errors are set to 1e-17 to classify given image correctly.

3. EXPERIMENTS & RESULTS

A complete hardware and software system is designed and implemented in the Robot Vision Laboratory of the Department of Mechatronics Engineering at the Atılım University. The ultimate goal of the larger project (umbrella project) is to develop a humanoid robot with a narrower application like Guide robot, Guard robot, Office robot, etc. The developed system has been tested for many live acquired images and results are satisfactory for such a pioneering work in the department. Improvements are required for better performance. System description and possible improvements are discussed in this chapter.

3.1. System Hardware

System has three main hardware parts. They are computer, frame grabber, and camera. Sony EVI-D100P camera and Imagenation PXC 200A frame grabber from CyberOptics are used.

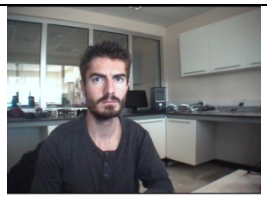
3.2. System Software

Algorithm of system is implemented on MATLAB R2011a software. Image Acquisition Toolbox, Image Processing Toolbox, and Neural Network Toolbox are used for algorithm development.

3.3. Face Detection

First implementation of system is performed on detection of faces in acquired image. Therefore, face detection has started with skin like region segmentation.

Besides RGB gives the best result, colors of wall inside laboratory can be skin like color due to white balance value of camera. Unwanted skin like color regions can affect detection and distort face shape. This color problem can be eliminated by white balance correction of acquired image. The implementation of white balance correction is given Figure 9. Wardrobe color is white in real (Figure 9). On the other hand, color in acquired image (left image) is cream and also wall color looks like skin color and it affects segmentation results. Figure 10 shows the results of segmentation on acquired image and white balance corrected image. Results shows that white balance correction should be applied after image is acquired.



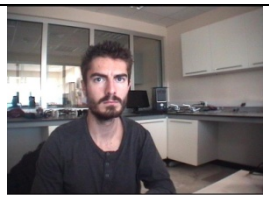


Figure 9 An Image Without (Left) and With (Right) White Balance Correction

Figure 10 Skin Segmentation Results on Acquired (Left) & Corrected Image (Right)

To guarantee color correction both segmentation are performed on acquired and corrected image, then logical “and operation” is performed. After segmentation is performed, morphological operations and candidate search is achieved as described in the previous chapter.

In order to use edge detection, Laplacian of Gaussian (LoG) filter can be used. LoG filter has low responses than edge detection. It makes usefull enhancements on facial features. Results of LoG filter are better than previous three trials. Mouth is more significant than others and eyes can be selected more accurately.

3.4. Face Recognition

With addition of isosceles triangle approach, as described in the previous section, eyes and mouth are found and cropped face image. Then, database of face images can be generated.

Database is generated from 26 people with 4 samples image for each person. Database is created from face detection part.

Pattern Recognition Tool in Neural Network Toolbox is used to generate and train neural network. The generated network consists of 2 layers with sigmoid transfer function. 2 layers are hidden layer and output layer. Output layer has 26 neurons and Hidden layer neuron numbers are 41.

3.5. Face Recognition System

Finally, face detection and recognition parts are merged to implement face recognition system. System can also handle more than one faces in the acquired image. Code is generated on MATLAB environment. Results are shown in Figure 11 – 12.

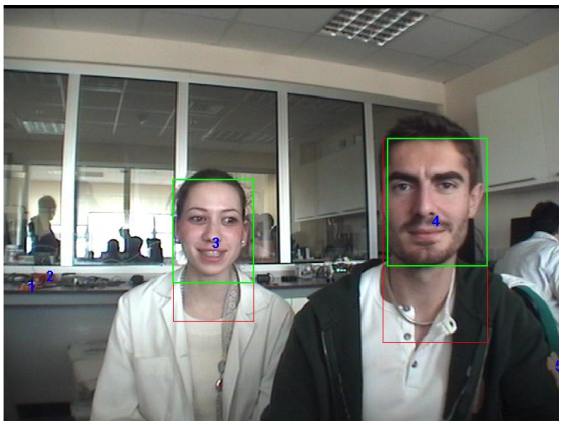


Figure 11 Acquired Image and Found Candidates

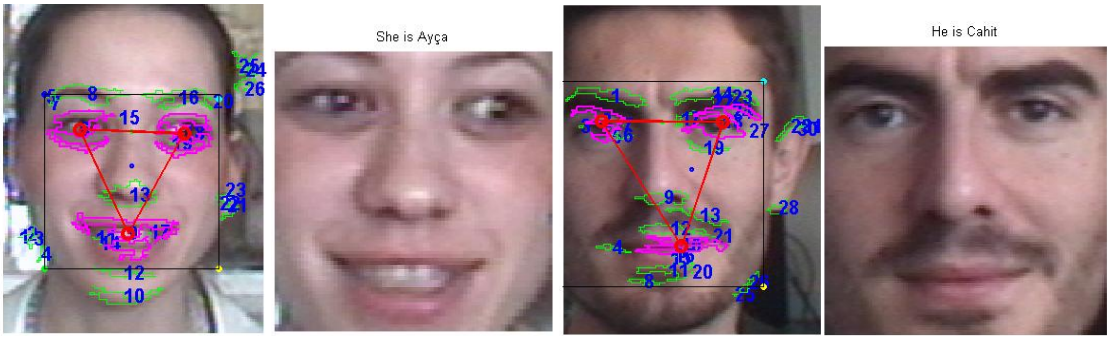


Figure 12 Facial Features Extraction on Face Candidates and Classification of Face Image (MATLAB Output)

Experiment and results are shown that algorithm can find multiple faces in the acquired image and classify correctly. This results important, since some methods can only detect one face in a given image.

Also, an image is taken when the eyelashes are closed. The recognition is correct with the 99.0498 result. On the hand, some experiments made on people that are not available in the database. System detects faces and network outputs are maximum of 52.7422 for other person and 1.3872 for another person. The algorithm identify face is the output of network is greater than 90. Therefore, above results show that these persons will not be identified.

Many experiments are performed on live acquired images. Face detection and recognition parts performed well. Skin segmentation both decrease computational time and search area for face. Experiments show that connection is established well between detection and recognition parts. The network can correctly classify when eye/eyes are closed, eyebrows are moved and face is smiled or showed teeth. Also, number of people in database can be increased and most probably will correctly classify faces.

4. CONCLUSION

Face recognition systems are part of facial image processing applications and their significance as a research area are increasing recently. Implementations of system are crime prevention, video surveillance, person verification, and similar security activities. The face recognition system implementation will be part of humanoid robot project at Atılım University.

The goal is reached by face detection and recognition methods. Knowledge-Based face detection methods are used to find, locate and extract faces in acquired images. Implemented methods are skin color and facial features. Neural network is used for face recognition.

RGB color space is used to specify skin color values, and segmentation decreases searching time of face images. Facial components on face candidates are appeared with implementation of LoG filter. LoG filter shows good performance on extracting facial compoments under different illumination conditions.

FFNN is performed to classifiy to solve pattern recongition problem since face recognition is a kind of pattern recognition. Classification result is accurate. Classification is also flexible and correct when extracted face image is small oriented, closed eye, and small smiled. Proposed algorithm is capable of detect multiple faces, and performance of system has acceptable good results.

Proposed system can be affected by pose, presence or absence of structural components, facial expression, imaging condition, and strong illumination.

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