ACCESS CONTROL SYSTEM USING FACE IMAGE

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Abstract: Ensuring safety requires the use of access control systems. Traditional systems typically use proximity cards. Modern systems use biometrics to identify the user. Use of biological characteristics to identify ensures a high degree of safety. In addition, the biological characteristics can neither be lost or stolen. This paper presents proposals for the access control system using the face image. The system operates in real timeusing the camera image.

Keywords: biometrics, face recognition, user identification, access control.

1. Introduction

Access control is the most often implemented security system. It difficult to imagine modern company or institution without this kind of system. Such system make restrict access possible to some compartment or zones for unauthorized persons. Access control has great significance for protection of building, persons, resources and information.

Access control systems usually work on the base of proximity access card, which has encode individual serial number in its memory. After the card is brought closer to a reader, the device decodes number, which is used to identification the user. Unfortunately, this kind of systems don't control who use the card – owner or unauthorized person. Additional the card can be loss or stolen.

Alternative systems without this disadvantages are systems using biometrics. System uses individual and unique biological features of person for user identification. The most popular features are: fingerprint, iris, voice and face image. Systems basing on face image have additional attribute (which haven't others), user doesn't have to know that his identity is being verified. The pattern can be taken through a hidden camera, whereas systems using fingerprint or iris require closeness to the reader. This feature of the system is the most frequently mentioned as a deficiency of access control systems, as users associated with treating them like criminals.

2. Propose system

To control system is fit for purpose must work in real time. In the case of identification of persons based on the facial image is a difficult task due to computational complexity.

Proposed access control system consists of following units: image obtainment, face detection and localization, face normalization, features extraction, identification. Scheme of that system is shown on Fig.1. Hybrid method of face localization using skin detection and template matching is applying as first part of system. When face is localized than face is normalized. Next, wavelet transform is used for features extraction. Hidden Markov models are used for training and testing procedure during identification process. Decision is made on the base maximum likelihood.

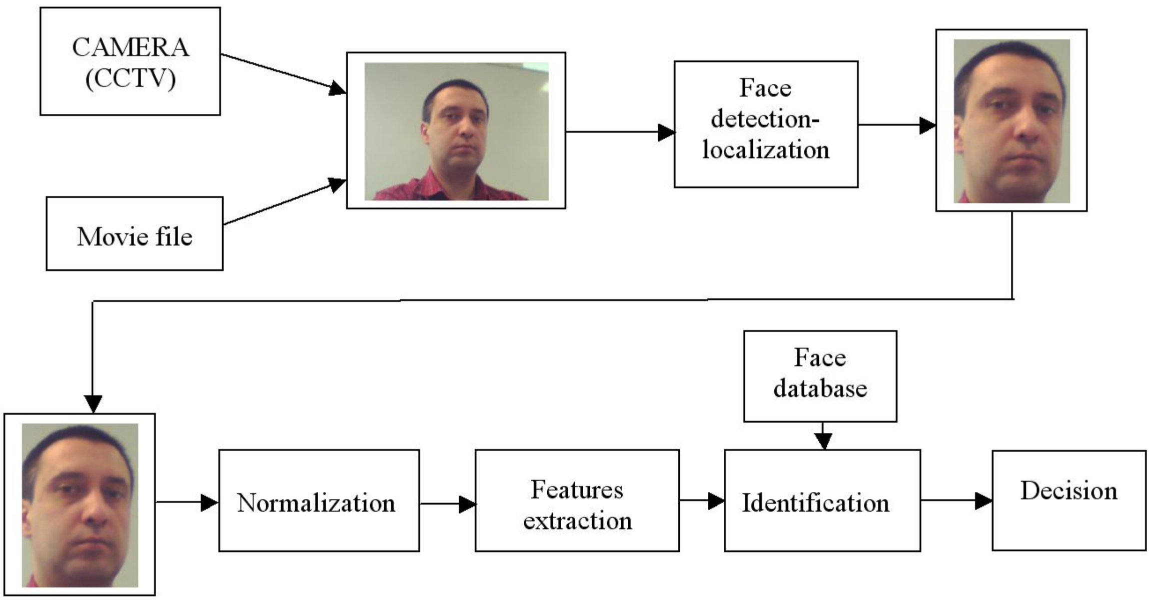

Fig.1. Scheme of real-time face recognition system

3. Face detection

The face detection problem is very important in complex user identification systems. This is the first part of processing path. The success of identification (recognition) depends on effectiveness of face detection and localization. If there is no face – there is no recognition.

There are many methods of face detection. The most popular group of methods are methods based on skin colour detection. They use some colour space as RGB, HSV, YCbCr or others [1,2,3]. Disadvantages of these techniques are following: many false positive errors, sensitive on change of lighting condition and type of light (bulb, fluorescent, sun).

The second group of face detection methods consists of methods using the template matching. The idea of these techniques is to make a comparison of an input image with the pattern including the face [4]. They have good recognition rate, but they are computationally expensive, because they need the whole image for analysis.

The methods using features form the third group of techniques of face detection. They may use Eigenface (PCA/KLT), Hidden Markov Models, Support Vector Machines or statistics. They are very effectiveness but also are complicate and computationally expensive.

3.1 Skin colour detection

The face localization over colour image use technique named skin colour detection. This is made with quantization of colourspaces, segmentation of image and next separate the regions of skin. We need to verify each region that it is face or not, obviously.
The most popular use colorspace are: RGB, HSV, YCbCr.

RGB

RGB is a colorspace originated from display devices, it describe colour as a combination of three coloured rays: Red, Green and Blue. It is one of the most widely used colour spaces for processing and storing of digital image data [2]. We can use simply segmentation on RGB colorspace (1) [5]. The result of application of this technique is shown on Fig.2.

$$\begin{gathered}\frac{R}{G}-\frac{B}{G}>Threshold \\ R,G,B=0..255\end{gathered} \tag{1}$$

HSV

Hue-saturation based colour spaces were introduced when there was a need for the user to specify colour properties numerically. They describe colour with intuitive values, based on the artist’s idea of tint, saturation and tone. *Hue* defines the dominant colour (such as red, green, purple and yellow) of an area, *saturation* measures the colourfulness of an area in proportion to its brightness. The ”value” is related to the colour luminance [2]. It may be use for skin detection (3) [3]. The result of application of this technique is shown on Fig.3.

$$
\begin{aligned}
&\mathrm{H} < 0.15 \;\; or \;\; \mathrm{H} > 0.95 \\
&\mathrm{S} < 0.68 \\
&\mathrm{V} > 0.3 \\
&H, S, V = [0,1] \\
&R, G, B = [0,1]
\end{aligned} \tag{3}
$$

Values H, S, V for skin detection selected experimentally.

YCbCr

YCrCb is an encoded non-linear RGB signal, commonly used by European television. Colour is represented by Y, which is luminance, computed from non-linear RGB, constructed as a weighted sum of the RGB values, and two colour difference values of chrominance *Cr* and *Cb* that are formed from components of RGB [2, 3]. The result of application of this technique (4) is shown on Fig.4.

$$
\begin{aligned}
&Y > 80 \\
&85 < Cb < 135 \\
&135 < Cr < 180 \\
&Y, Cb, Cr = 0..255
\end{aligned} \tag{4}
$$

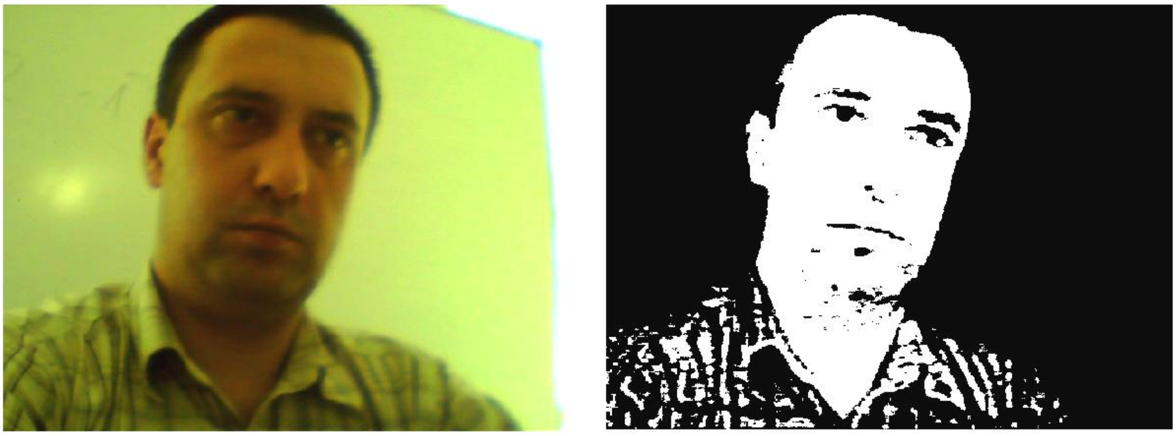

Fig. 2. RGB mask (1) for skin detection.

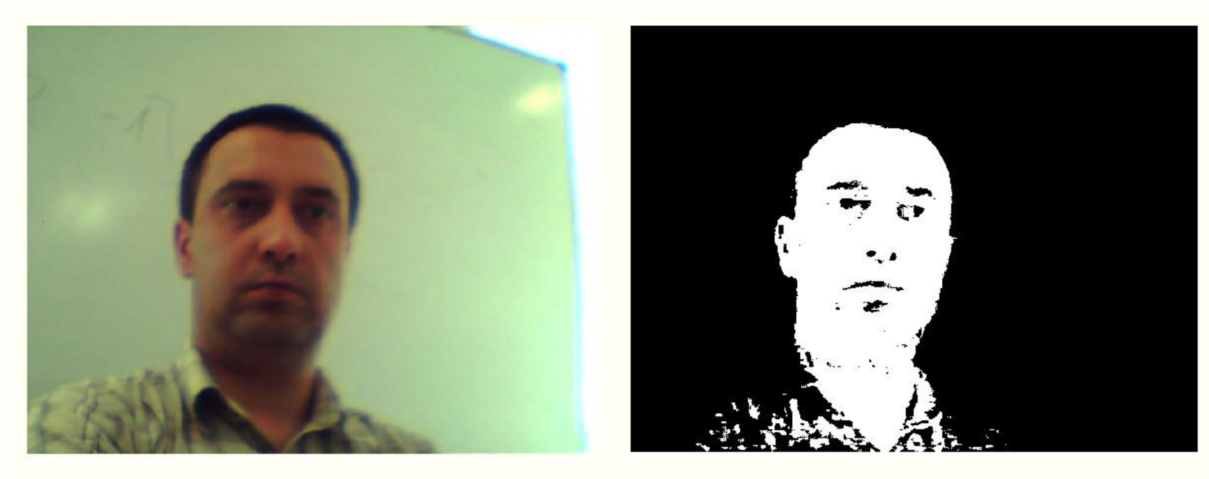

Fig. 3. HSV mask (3) for skin detection.

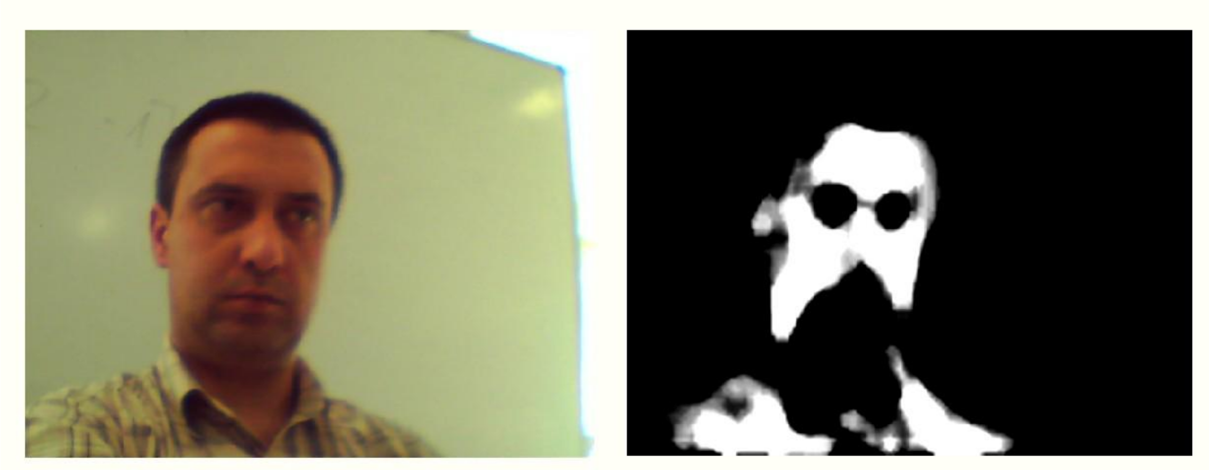

Fig. 4. YCbCr mask (4) for skin detection.

3.2 Template matching

The template matching technique is used for classify object, which compare part of image to another one and may be used to recognize similar object. The template matching method for face detection uses the pattern of face [4, 6]. Pattern of face is comparison with whole input image from the top to the bottom, and from the left to the right. It is computationally very expensive. Additional this type of face detection methods are characterized by frequent non-face errors.

3.3 Propose method of face localization

Above presented face detection methods have some advantages and disadvantages. Therefore below there is presented the own detection method.

This method uses skin detection technique for selection potential areas containing a face. RGB colour space is use in this step. Next, template matching technique is applied to verify each region that it is the face or not. The difference of this method from the others is that it uses image of eyes as a pattern (Fig. 5) and not whole face - as most methods.

Algorithm:

1. *Start*
2. *Take a frame(image) from video stream.*
3. *Make a quantization to HSV colour space.*
4. *Analyse image with equations (3).*
5. *Make a mask.*
6. *Select areas of skin.*
7. *For i=1 to numbers_of_skin_areas*
   7.1 Take size of area.
   7.2 Scale pattern of eyes adequately to size of skin area.
   7.3 Compare pattern with area: if distance<threshold than save coordinates of face.
8. *If number_of_ frame= end than STOP, else go to 2.*

Fig. 5 Samples of eyes pattern

4. User Identification

The user identification process work on the basis of the frontal facial image, in which the fusion of Wavelet Transformation (WT) and Hidden Markov Models (HMM) are used for the three parts of face (eyes, nose, mouth); the decision is made on the basis of the sum maximalisation of likelihood of generating of the models observation.

The most popular method of face identification is Principal Component Analysis (PCA) [3, 7]. Other popular methods use Wavelet Transform [8] or Hidden Markov Models [9].

Analysis of the existing solutions revealed their defects, which caused their weak effectiveness. The disadvantages of these methods are as follows:

– In case of the new user's registration, process of learning and addition his/her facial image to a database, requires repeated learning of the whole system.

– They work with whole face.

– They are computationally very expensive.

The proposed method is a combination of two mathematical tools, Wavelet Transform (WT) and Hidden Markov Model (HMM). Both were mainly used for speech recognition. Here, WT is used for features extraction, and HMM for identification. This system works in two modes, learning and testing. These modes differ from each other. The algorithm of this method consists of four main parts:

1. Pre-processing: normalization and face division into three parts
2. Features extraction: WT of the face image
3. Training: generating and learning HMM for each part of the face
   Testing: testing models from the database
4. Training: saving to database the learned models of the face
   Testing: making a decision - maximum likelihood of the model

4.1 Pre-processing

The normalization consists of fixing the centers of the eyes, and then respective scaling of face so that the distance between them equals 120 pixels. The second part of this process is division of the normalized face into three parts: the area of eyes, nose, and mouth (Fig.6).

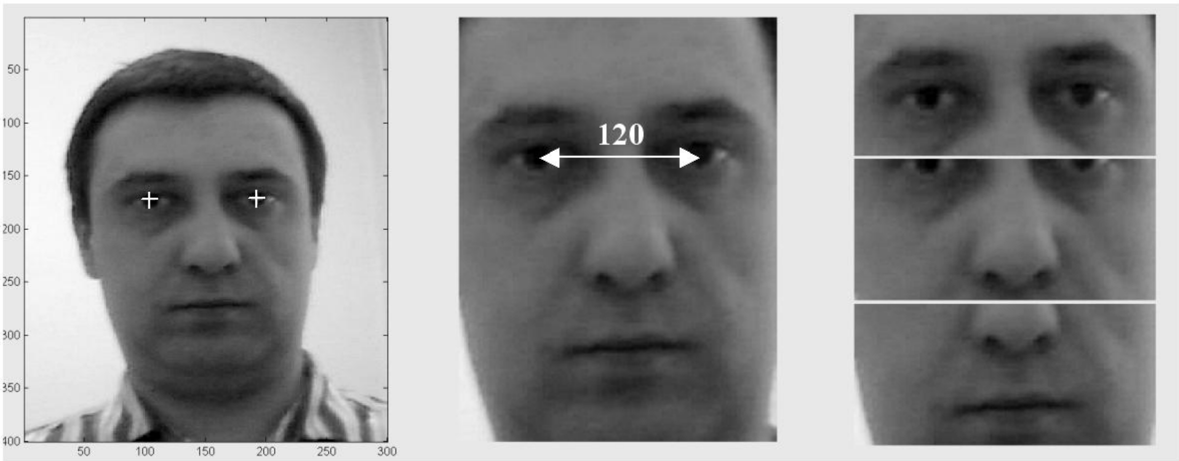

Fig. 6. Pre-processing of the face image

4.2 Features extraction

WT is used for features extraction. Using 2D WT (Fig. 7), the face image is decomposed into four sub images via the high-pass and low-pass filtering. The image is decomposed along column direction into sub images to high-pass frequency band *H* and low-pass frequency band *L*. Assuming that the input image is a matrix of *m* x *n* pixels, the resulting sub images become *m/2* x *n* matrices. At the second step the images *H* and *L* are decomposed along row vector direction and respectively produce the high and low frequency band *HH* and *HL* for *H*, and *LH* and *LL* for *L*. The four output images become the matrices of *m/2* x *n/2* pixels. Low frequency sub image *LL* (A_1) possesses high energy, and is a smaller copy of the original images (A_0). The remaining sub images *LH*, *HL*, and *HH* respectively extract the changing components in horizontal (D_{11}), vertical (D_{12}), and diagonal (D_{13}) direction [10].

Wavelet Transform of the second level (Fig. 8) is used for features extraction in the proposed technique. After first level wavelet decomposition, the output images become the input images of the second level decomposition. The results of two-level 2D WT are coded in this way, so that they can be applied in HMM (Fig. 10). One of the simplest methods of reduction and information coding is calculating of standard deviation or mean value. Each part of the face is transformed separately by discrete wavelet transform (Fig. 9). The bank filters' selection is an important thing in this transformation. It guarantees a good recognition rate [11].

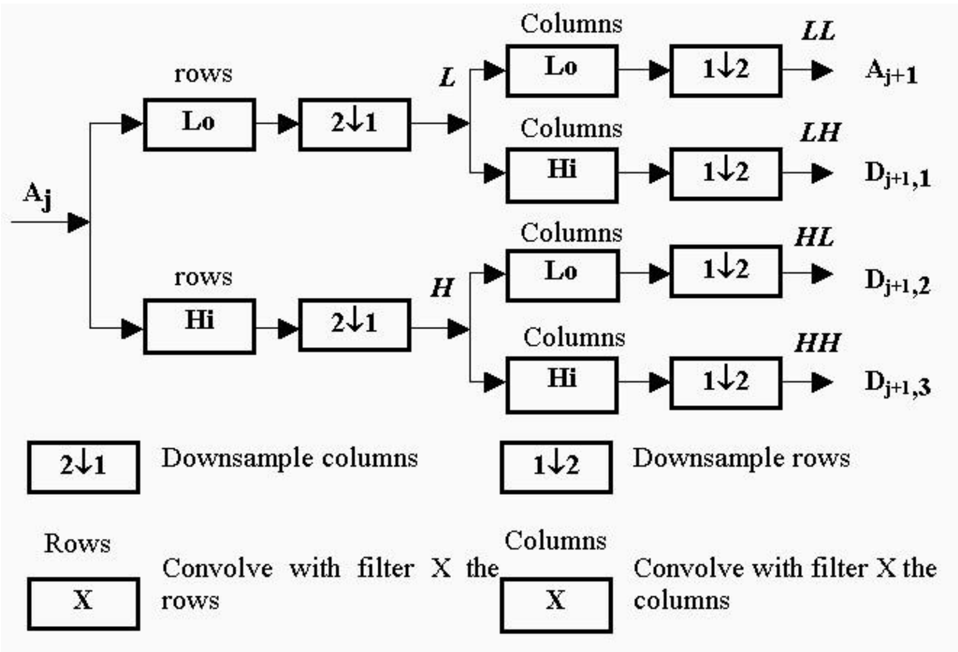

Fig. 7. Scheme of one-level two-dimensional wavelet transform [14].

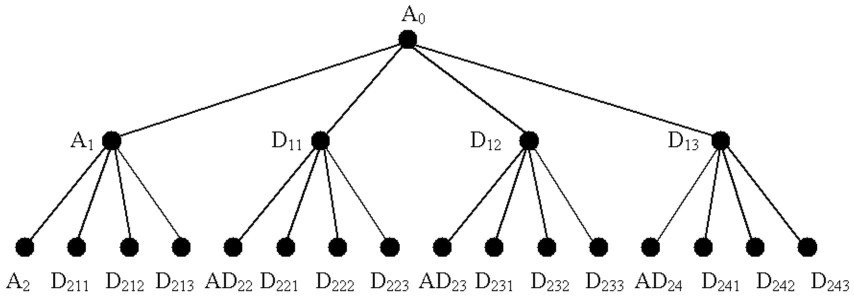

Fig. 8. The wavelet decomposition tree.

Fig. 9. Example of level 2 of the wavelet decomposition of image of eyes area.

4.3 Training system

HMM is used for the identification process. HMM is a double stochastic process with underlying stochastic process that is not observable (hidden), but can be observed through another set of stochastic processes that produce a sequence of observation.

Let $O=\{O_1,,O_T\}$ be the sequence of observation of feature vectors, where T is the total number of feature vectors in the sequence. The statistical parameters of the model may be defined as follows [12].

- The number of states of the model, N
- The transition probabilities of the underlying Markov chain, $A=\{a_{ij}\}$, $1 \le i,j \le N$, where a_{ij} is the probability of transition from state i to state j subject to the constraint $\sum_{j=1}^{N} a_{ij} = 1$
- The observation probabilities, $B = \{b_j(O_T)\}$, $1 \le j \le N$, $1 \le t \le T$ which represents the probability of the t_{th} observation conditioned on the j_{th} state.
- The initial probability vector, $\Pi = \{\pi_i\}$, $1 \le i \le N$.

Hence, the HMM requires three probability measures to be defined, A, B, π and the notation $\lambda=(A,B,\pi)$ is often used to indicate the set of parameters of the model. In the proposed method, one model is made for each part of the face. The parameters of the model are generated at random at the beginning. Then they are estimated with Baum-Welch algorithm, which is based on the forward-backward algorithm. The forward algorithm calculates the coefficient $\alpha_t(i)$ (probability of observing the partial sequence $(o_1, \ldots , o_t)$ such that state q_t is i). The backward algorithm calculates the coefficient $\beta_t(i)$ (probability of observing the partial sequence $(o_{t+1}, \ldots , o_T)$ such that state q_t is i). The Baum-Welch algorithm, which computes the λ, can be described as follows [13].

1. Let initial model be λ_0
2. Compute new λ based on λ_0 and observation O
3. If $log(P(O|\lambda) - log(P(O)|\lambda_0) < DELTA$ stop
4. Else set $\lambda_0 \leftarrow \lambda$ and go to step 2.

The parameters of new model λ, based on λ_0 and observation O, are estimated from equation of Baum-Welch algorithm [13], and then are recorded to the database.

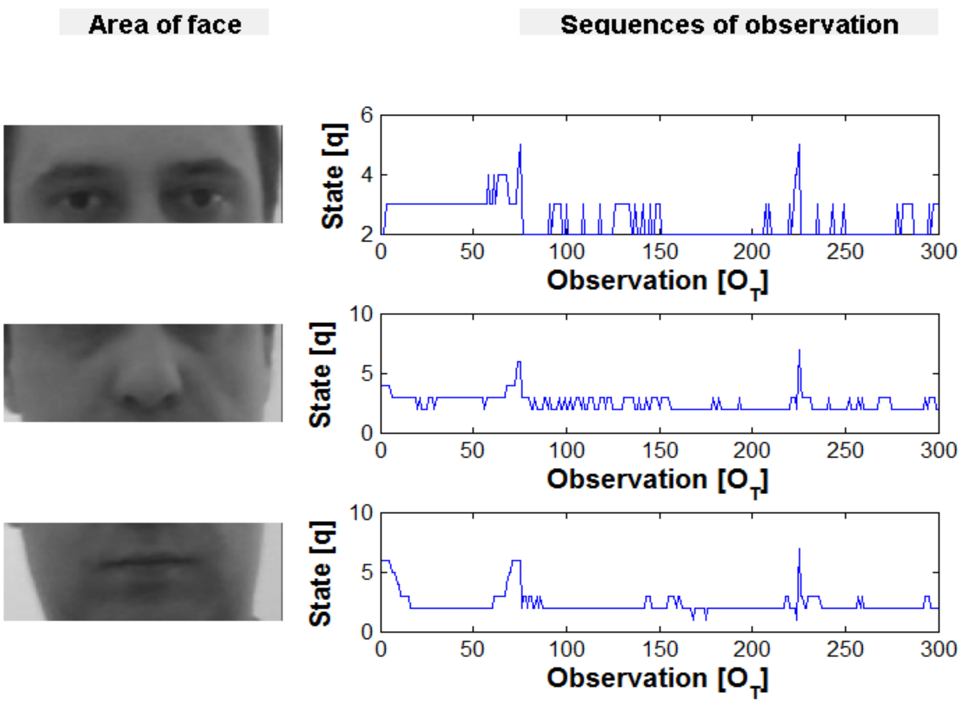

Fig. 10. Part of face and correspond them sequences of observation.

4.4 Testing system

The testing process consists of computing the probability of observation generating by the models saved in database and choosing this model for which the likelihood is maximum. In the proposed method, probabilities are calculated separately for each of the three models representing parts of the face, and then they are added. The face, for which the sum of probability is maximum, is chosen as the correct face. The probability of generating sequences of observations is computed from the equations 5-8 [13].

$$P(O \mid \lambda) = \sum_{q} P(O \mid q, \lambda) P(q \mid \lambda) \tag{5}$$

$$P(O \mid q, \lambda) = \prod_{i=1}^{T} P(o_t \mid q_t, \lambda) = b_{q_1}(o_1) b_{q_2}(o_2) \ldots b_{q_T}(o_T) \tag{6}$$

$$P(q \mid \lambda) = \pi_{q_1} a_{q_1 q_2} a_{q_2 q_3} \ldots a_{q_{T-1} q_T} \tag{7}$$

$$PF = \sum_{i=1}^{3} P(O_i | \lambda_i) \tag{8}$$

5. Experimenting

The system has been tested in real environment and obtained recognition rate 75 %. The face detection module is sensitive on face rotate and different lighting conditions and type of lights and by reason of this its face detection rate is 83%. The face recognition module is sensitive on face rotate and by reason of this its face recognition rate is 92%.

This system gives acceptable results in comparison to others methods [15, 16] (Table 1 and Table 2).

Table 1. Comparison of face detection methods

Method	**Detection rate**
Eigenvector	92 %
SVM	75 %
Neural Network	81 %
Template matching	80 %
Proposed – skin&eye	83 %

Table 2. Comparison of face recognition methods

Method	**Recognition rate**
Eigenvector	94 %
HMM	84 %
Neural Network	93 %
Proposed – HMM&WT	92 %

6. Conclusion

Article presents control system of user access, which is based on face recognition method work in real-time. Recognition rate of the hole system is 75%. Error rate (25%) is the result of overlay errors of detection face module (17%) and recognition module (8%). The hole system is sensitive on face rotation. Future works would be concentrated on elimination this problem by detection and rotate face along X axis, and add other pose of face aim elimination of rotate face along axes X and Z.

Proposed method of user identification is characterized by usage of the three areas of the face for identification and creating for each of them one independent HMM (which it is possible to use separately or together). This procedure gives possibility to short calculation request and permit obtaining a good recognition rate. On the basis of experimental research it was stated the area of eyes contains the most useful information for the persons' identification, and it could be successfully applied in specific methods of identification.

Additional advantage of the method is that, in case of the new user's registration, the process of learning and addition his/her facial image to a database, does not require repeated learning of the whole system.

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