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USE OF FACE RECOGNITION SOFTWARE BY KARHUNEN LOVE METHOD

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Abstract:
Numerical simulations and checks of face recognition software on given image databases represent a type of empirical research. Face recognition software works on the principle of comparing a photo of the person's face with the photos in the database. The operation of face recognition software can be divided into three stages. The first stage is face detection, the second stage is face tracking and the third stage is face recognition. For this purpose, software solutions have been developed, with different work techniques. However, it is characteristic that regardless of the different techniques, each expresses its effect with a probability expressed in percentages. Simply put, for now, no software solution can be said to be 100% effective. For now, no computer solution can be compared to the human ability to recognize and identify a person.

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1. INTRODUCTION

The starting point of research in this area should be based on the foundations on which the human ability to recognize faces rests. Human ability is largely based on biometrics. Biometrics includes not only facial recognition but also recognition by walking, handwriting, fingerprinting, oice recognition, etc. [1-5]. There are constant changes that occur naturally in the appearance of people, e.g. aging or facial changes caused by the use of various artificial aids, such as makeup, beard, mustache, drug use, etc. These are the problems that the software has to deal with in the sense of unifying all the differences that have arisen in the examined photograph and connecting it with the photograph in the database. For human recognition, all these changes that occur over time are almost no problem. People can recognize faces in a photo of poorer quality [6] in terms of age or low resolution [7]. Very little information is needed to recognize people's faces. Only one property can be enough, e.g. eyes or eyebrows. Paper [8] states that the following fields are important for the identification of eyes, eyebrows, tip of the nose, and lips. This paper also explains how caricature versions of a person unequivocally indicate the right person, just as if it were a true portrayed person. From the mentioned research, it can be concluded that color and pigments play an important role in recognition, especially when the shape of the face in the photo loses its shape. On the other hand, the negative contrast of the image dramatically impairs the recognition of e.g. faces that are illuminated from above. The research concludes that recognition is based on spatial relationships between parts of the face as well as the shape of the face itself. The spatial relationship between parts of the face can be disrupted through aging, plastic surgery, drug use, and the like.

The use of computer software for face recognition is no longer based solely on scientific purposes, they are also applied in state security services, in improving human-computer interaction, and in other commercial applications. In many of the world's metropolises, such systems are used to

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make it easier for state security services to locate a suspect [9,10]. However, what is characteristic of all software is that they express their results in a percentage of success that is less than 100% [11].

2. FACE RECOGNITION AS KEY EVIDENCE OF ITS EXPERTISE

Recognition of faces by people is key to identifying and recognizing the requested person. The human face also reveals many other attributes related to the person, such as age [12], gender [13], family affiliation in terms of similarity with parents or close relatives, as well as the emotional state [14] and current mood of the observed person [15]. People without great mental effort easily and in a split second compare the detected face with the face stored in human memory. The goal of computing is to follow the algorithm of human recognition and to eventually achieve the same or higher probability of recognition concerning humans. The problems faced by computer systems are image quality in terms of pixelation, lighting, contrast, then facial expressions from happiness to bad mood, as well as the up-to-dateness of the database itself. When it comes to the problem of image resolution, it is logical that it can be solved by using a camera that takes high-resolution images. The higher resolution carries more detail about the image so it can be more easily identified. On the other hand, more pixels require a better processor or longer processing time. The problem is not completely solved by increasing the resolution. The difference in whether a person was photographed from one or more meters is also important for computer identification.

Many studies have shown that eyebrows are one of the most important features of the human face [16,17], even compared to the eyes. Many claims that eyebrows are, roughly speaking, antennae for conveying emotions and the current state. Eyebrows are also a very stable facial feature and can survive large photographic degradations. It should be emphasized that people possess a wide range of physical eyebrow movements that cannot be measured with eye or mouth movements. According to research [18], the fields important for identification are eyes, eyebrows, the tip of the nose, and lips. From the above research, the identity of a person can be determined based on one or two parts of the face. E.g. lips or eyes or tip of the nose

There are two basic ways in which people can be distinguished: face shape and the way light is reflected (pigmentation).

The term pigmentation surface means all surfaces that have reflective properties, including albedo; shades, irradiation, etc.

Albedo is a measure of the power of light reflection possessed by a surface or body.

Shades are the main property of color, usually expressed in hexadecimal values in computer graphics, so for example, the mark for dark red is # 660000. One base color can have different hue values, e.g., light blue, sky blue, dark blue, and many shades between the above.

Irradiation is a measure of the irradiation of an area. An illuminated (irradiated) surface has two possibilities: one is to reflect light, and the other is to transmit light and not cast shadows.

Lighting has a primary role in facial recognition [19]. Eg people find it easier to recognize faces when the picture is in color. This statement is most easily proven by the example of recognizing a person who is on the move. It is illuminated in different ways and presents a problem of recognition. It can be concluded that the negative contrast of the image greatly impairs recognition. In addition to all the listed terms that affect face recognition, the following should be noted: posture, lighting, and facial expression. Different facial expressions can also lead to recognition errors. In the developed software model, many examples of testing the required image with the image in the database are presented. Truth be told, we cannot state a 100% effect, but what is characteristic of our software is that the image of the requested person is always among those offered, but sometimes it is not the first, due to the described problems. With the help of human recognition power, a computer error can be corrected and the requested person can be connected to the person in the database. For the practical application of the developed software, it is proposed that the images in the database be named after a unique ID number. This would facilitate the identification process. When the computer finds a similarity, the security structures determine the identity of the person by searching the other number of the security structure.

3. MATERIALS AND METHODS

3.1. Computer recognition of faces from video content

Computer face recognition is performed in three stages: Face detection is the first step in the enumerated sequence of computer face recognition. In this step, the system must mark and identify in the picture or video what is on the face of everything in the photo. After the system identifies the face, part of the photo with the face information is extracted into the face classification system. The second step is face tracking which means that the face can be tracked constantly if the person is moving. The third step is the face recognition stage, which takes into account the faces found in the face detection step and compares them with the faces in the image database. The previous two stages have been thoroughly improved, while the third has room for further research. This stage is the subject of research. The software has been created whose main role is to recognize the required person, based on a given database. Their goal, among other things, is to help IT experts find solid evidence in court. Video content is represented by a series of photos, depending on the standard applied the number of photos per second of video content varies. The extracted photo from the video content can be compared with the photos from the database. The problem of recognizing a photo from video content is reflected in the following: photo quality (resolution, contrast, lighting, etc.) the distance of the camera from the person's face. The recognition procedure takes place in the following way, recorded samples are taken from the video content of one or more cameras, from which a representative representation of the face is taken. A representative sample of the face is compared to the face from the base. It should be emphasized that the circumstances of recognition from video content are aggravating for the above reasons.

The software solution is based on various mathematical techniques that use image pixels for recognition, as arguments for mathematical functions. As a result, an output composed of several similar persons was obtained. By careful observation, the wanted person can be identified.

3.2. Data collection

Test data (photographs) were collected from two sources: self-portraits and downloads of publicly available databases of photographs taken for this purpose. In that sense, two databases were used: one with black and white images, .bmp format, and the other with color photos in .jpg format.

To remove unnecessary parts from the photo, e.g. GIMP software is used in the background. All photos were taken in four folders under the names:

- ✓ preparation_bmp;
- ✓ preparation_jpg;
- ✓ JPG testing database;
- ✓ BMP testing base.

Preparation_bmp is a folder containing twenty photos (black and white), size 112x92, bmp format. These are photographs of twenty different people taken under strictly defined conditions in full face. These are the same conditions that apply to photographs in personal documents. In the practical case of using software for state purposes, photographs of persons from personal documents should be found within this database. It is recommended that the photos be named after the registration number when entering them into the database. This would facilitate the search process and then the software offers a photo recognition solution named after the citizen's ID number. Furthermore, the identity can be very easily revealed based on the unique personal identification number of the citizen.

The Preparation_jpg database is a database containing fifty-three photographs, 100x100 p., .Jpg format. It should be noted that photos of different sizes can be taken within this database. No need to use additional software to bring the photos to the required size. The software brings them to the required size. This database consists of photographs of fifty different people taken under strictly defined conditions, as in the previous case, for personal documents, for possible use for state purposes. The recommendation is the same as with the previous database, that the photos be entered according to the personal identification number when entering them into the database, which would facilitate the identification process. Different image formats are adapted to different identification techniques developed as a software solution. As already mentioned, these photographs are first translated into 2D black-and-white photographs (arrays or matrices) and as such is roughly referred to as mathematical procedures.

The base for BMP testing in our specific case consists of two hundred photographs. These are photos of twenty people from the preparation_bmp database, with different facial expressions: smiling, sad, with different looks, with glasses, and the like.

It is a database of photographs of these people taken at the right time. The task of the developed software solution is to connect the person from the bmp testing database with the person from the bmp preparation database. It should be emphasized that the more photos from the bmp test database similar to all faces, the higher the probability of recognition.

The base for testing JPG in this particular case consists of five hundred photographs. These are photos of people from the preparation_jpg database, with different facial expressions, as in the previous case. It is a database of photographs of these people taken at various times. The task of the developed software solution is to connect the person from the jpg testing database with the person from the jpg preparation database. Also, in this case, the above condition applies that the photo from the jpg test database is as similar as possible to all faces. When downloading material from the video content, you should focus only on those photos that are more similar to all faces and take those if possible that were taken at the same or similar distance.

4. RESULTS AND DISCUSSION

4.1. Data processing

The Matlab software package has developed software codes for database preparation, software codes for database testing, and codes for two vectors within the following method: Karhunen-Love. These codes are summarized in the following functions: Karhunen_Loeve (ENT and JPG).

Example 1.
a = imread (face10, bmp);

With this command, which we typed directly into the command window of Matlab, we called a photo called face10, bmp format from the database and which we want to test. For example, it is a picture of a suspect created at the crime scene. Then, we call the function:
Karhunen_Love_orl (a, 20)

The number 20 indicates the existing number of photos in the database. The search result is presented in Fig. 1.

In this case, the network response is missing. The software did not recognize the person, but the requested person is on the list of offered. It does not take much effort for a person to draw a conclusion and connect the requested person with the one offered.

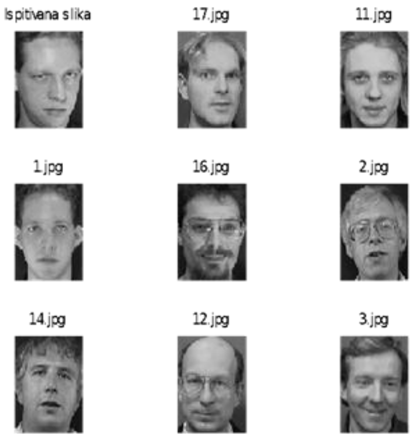

Fig. 1. Search result for face recognition with function Karhunen_Loeve_orl

Example 2.
a = imread (S20_10.jpg)

With this command we called a photo named S20_10, jpg format from the database, which we want to test. As in the previous case, this is a picture of the suspect created at the crime scene. Next, we call the created Matlab function:
Karhunen_Love_jpg (a, 53)

The number 53 indicates the existing number of photos in the database. The search result is presented in Fig. 2.

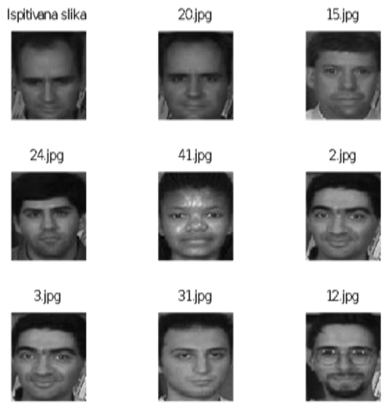

Fig. 2. Search results for face recognition with function Karhunen_Loeve_jpg

In this particular case, we have the network's response. The software recognized and connected the requested person. From the attached result, it can be concluded that there are significant facial differences between the requested photograph and the related person in the database, but it was not a problem for the software to unify the differences.

4.2. Description of the human face recognition model

Recognition of the human face using computers and artificial intelligence is an open scientific problem. At first glance, trivial for a man, for a machine, recognizing a human face is still a problem, which is why the term - probability of recognition is used. Computers, on the other hand, can search large millions of databases in seconds, so the speed is their primary advantage over humans. Different facial expressions and head positions in humans can lead to the machine connecting some completely different people in some cases. However, the percentage of recognition in modern software is over 95%, although it should be emphasized that this is true in certain conditions. All these software can be divided into several categories:
Decomposition of vector images along with certain directions in the image space (Karhunen - Loeve, PCA analysis, Fischer method, etc.) [20];
Neural networks [21,22];
Quantum neural networks and internal spaces
Face-matching techniques (comparing the characteristic dimensions of faces with samples from a database) and reconstruction of a character in 3D space [23].

If we compare these models, from the point of view of technical applicability in everyday practice, we could say that face-matching techniques and neural networks have an advantage in terms of commercial application. These techniques are most often used for video surveillance of a certain space and various biometric recognition to identify a certain person. It is important to emphasize that in terms of scientific research work, all methods are being developed, and in the further presentation, we will explain the Karhunen-Loeve method [20]. In that sense, the question of the criteria according to which the final classification of the input data image will be performed is raised. Namely, the formats of these images are standards: .jpg, .tiff, or .bmap, and they are deposited in the computer memory as 3D arrays, which are later translated into 1D arrays to perform the necessary mathematical operations. The values of the members (pixels) of this array, as 8-bit, vary in the range of 0-255 (grayscale). Ultimately, the image can be represented as a 1D array: X={x_1, x_2… . .x_N} so that the distance between two vector images is the norm of their difference:

$$d = \|X_n - X_m\| = \sqrt{(x_{m1} - x_{n1})^2 + (x_{m2} - x_{n2})^2 \dots.(x_{mN} - x_{nN})^2} \quad (1)$$

where the pixel values of the image are x_1, x_2… … … .x_N. Simply put, the minimum distance between two images in a database is a criterion for their identification. All these photographs, which are listed below in the text, come from a publicly available ENT database, which can be used for scientific research purposes [24]. Photographs of 20 different persons with the full face (facing the viewer) were used to form a database, while their various facial expressions and head positions were used for recognition. Each person had 10 different facial expressions and positions, so a total of 200 photographs were used in facial recognition experiments.

4.3. Karhunen-Loeve Method

This method is based on the idea of data compression, so it is necessary to use fewer bits in the computer's memory to store them [25,26]. This achieves a more efficient performance of mathematical operations on data. The Karhunen-Loeve method is essentially a linear transformation that achieves the decorrelation of data, by transforming their basis vectors (the basis in which data values are represented) into new mutually orthonormal vectors. For example, if we represented the pixel values so that the horizontal axis (x-axis) is the pixel value and the vertical axis (y-axis) is the adjacent value (say, right), we would get the image pixel correlation curve in the 2D coordinate system. A linear transformation of this coordinate system, such as a rotation, would lead to a new coordinate system in which adjacent pixels would be mutually incorporated. In other words, the dependency curve would have a completely different shape. To better understand this method, let us consider its theoretical foundations [27]. The decorrelation of data refers to the notion of random variables, since, as is well known, its values are incorporated, which can be expressed in terms of mathematical expectation E:

$$E(x_i x_j) = \begin{pmatrix} 0; i \neq j \\ 1; i = j \end{pmatrix} \quad (2)$$

where x_i,x_j the values (or realizations) are random variables x_m. In the random variable the probabilities of the realization of the event x_i are the same: p_i=1/N so that from the definition of mathematical expectation follows:

$$E(X_m) = \sum_{i=1}^{N} p_i x_i = \frac{1}{N} \sum_{i=1}^{N} x_i = X_{sr} \quad (3)$$

As can be seen from the above formula, the mathematical expectation of a random variable is equal to its mean value X_{sr}. The following applies to random variables: $X_{sr}=0$ as we will see later, this also has important implications for the Karhunen-Loeve method. Of course, when loading an image for processing, it cannot be claimed to be a random variable. In general, the mean value of an array X={x_1, x_2… .x_N} can be made zero by subtracting the mean value from each member. So:

$$X^{'} = X - Xsr \quad (4)$$

It simply turns out that the mean of this array is zero:

$$X_{SR}^{'} = \frac{1}{N}\sum_{i=1}^{N} X^{'} = \frac{1}{N}\sum_{i=1}^{N}(X - X_{sr}) = X_{sr} - N \cdot \frac{1}{N} \cdot X_{sr} = 0 \quad (5)$$

The essence of the Karhunen-Loeve method is to find a linear transformation that will transform the array into a new array based on the relation:

$$Y^{'} = W - X^{'} \quad (6)$$

where is W a matrix whose species represent the new basis vectors, while the array X' is represented as a column matrix. The goal of this linear transformation is the decorrelation of array members, according to formula (2). The components y_i of the new vector Y′ are determined by simple matrix multiplication:

$$y_i = \sum_{j=1}^{N} W_{ij} \cdot x_j^{'} \quad (7)$$

Before proceeding further, let us state another important property of the matrix. Since it has already been said that the new basis must be orthonormal, this means that the basis matrix must satisfy the condition:

$$W^{'} \cdot W^T = W^T \cdot W = I \quad (8)$$

where I am the unit matrix (on the main diagonal of the unit and all other elements are zero). An important consequence of the above formula is $W^T=W^{-1}$ (inverse matrix). So the focus is on determining the matrix W. We show that the intensity of the vector during transformation (6) remains preserved, with the transformation defined as follows:

$$\|Y\|^2 = Y^T Y = (W \cdot X)^T (W \cdot X) = X^T \cdot (W^T W) \cdot X = X^T \cdot \mathrm{I} \cdot \mathrm{X} = \|X\|^2 \quad (9)$$

Consider further the covariance with the introduced linear transformation:

$$C_Y = E(Y \cdot Y^T) = E((W \cdot X)(W \cdot X)^T) = E(W \cdot (XX^T) \cdot W^T) \quad (10)$$

or:

$$C_Y = E(Y \cdot Y^T) = E(W \cdot (XX^T) \cdot W^T) = W \cdot E(XX^T) \cdot W^T = W \cdot C_x \cdot W^T \quad (11)$$

Formula (10) is crucial in this method. Namely, it is further:

$$\begin{gathered} W^T \cdot W \cdot C_x \cdot W^T = W^T \cdot C_y \\ I \cdot C_x \cdot W^T = W^T \cdot C_y \\ C_x \cdot W^T = W^T \cdot C_y \end{gathered} \quad (12)$$

Since it is necessary for the matrix C_Y to be diagonal with the elements λ_i on the main diagonal (this achieves decorrelation), formula (12) can be written in the following form:

$$C_x \cdot W_i^T = \lambda_i \cdot W_i^T; \quad i = 1,2 \ldots . M \quad (13)$$

Thus, the problem comes down to determining the eigenvalues of the covariance matrix C_x and for that purpose, special programming routines have been developed in higher programming languages, such as MATLAB, Octava, etc. The initial matrix X consists of images (matrix columns) which are translated into 1D vectors according to the described preprocessing procedure. In the MATLAB programming language, the eigenvalues according to formulas (12) and (13) are determined based on one programming line:

$$[W^T, C_y] = eig(C_x) \quad (14)$$

On such a specific basis W, there are usually several eigenvalues other than zero in the matrix C_y, usually no more than ten values on the main diagonal, which means that not all columns (base vectors) are taken into account, but only a set: *W (: , M), W (: , M - 1), .. W (: , M - k), M _* - number of columns in the database). This reflects the mentioned data compression. Within these k base vectors, the variance of the data is the largest, while for the others in the matrix it is negligible. To illustrate the above, consider the results of this method on the mentioned ENT base as shown in Fig. 3.

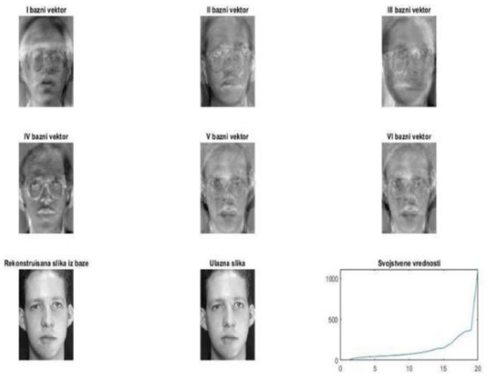

Fig. 3. Basis vectors and eigenvalues in Karhunen Loeve method

Starting from the first upper image in the left corner, the base vectors are thinned and as seen in the image in the lower right corner the values of the eigenvalues, starting from the end, drop very quickly to zero and it was enough to show six base vectors from *W (: , M) W(:, M - 5)* to it can be noticed that the reconstructed image is almost identical to the image in the database. Based on the described method, we can describe in detail the algorithmic procedure for recognizing a particular image in the following steps:

Load basic images that will form the basis for recognition. Translate them into 1D vectors on a gray, 8-bit scale (pixel value 0-255). Each image will then be a one-dimensional 1D column vector (size Nx1) X_iX_i and form a base of a total of M images:

$$X = [X_1 X_2 X_3 X_4 \ldots\ldots\ldots X_M] \qquad (15)$$

The matrix X will therefore be of size N x M.

Center the matrix so that its mean value is zero:

$$X' = X - (X_{SR}^T)^T \qquad (16)$$

In the above expression X_{SR}^T, it represents the mean value of the transposed matrix *X*. This mean value represents the size matrix *1xN*, which is why the transposed value $(X_{SR}^T)^T$ is taken (the size is obtained *Nx1*) so that it can be subtracted from each column of the matrix *X*.

Formation of the covariance matrix and calculation of eigenvalues. There are two program lines in the MATLAB programming language. Covariance matrix:

$$C_X = X^T \cdot X \qquad (17)$$

and calculating the eigenvalues of the new base:

$$[W, C_y] = eig(C_x) \qquad (18)$$

We will save in the computer memory, the *X* image database, the new basis W, the mean value X_{SR}, and the projections of the 1D vector in the database, KLCoef. Recall that in the Cartesian coordinate system, the projection of a vector on an axis (x, y, or z) can be obtained from the scalar product of a vector with ort vectors. Similarly, we act here with the formula:

$$KLCoef = X^T \cdot (X \cdot W) \cdot |C_Y|^{-1/2} \qquad (19)$$

where the repair $|C_y|^{-1/2}$ significantly contributes to a better reconstruction of the original vector. To check whether an image belongs to the database or not, we will determine its projection in the new database and then go through the entire database and compare it with the projections of the original vectors. Where the distance between the projections is minimal, we can assume that the image or vector examined is the one from the base. This is the essence of this method. So, let it be a test vector X_{new}. First, we will center it by subtracting the mean value of the database from it: $X'_{new} = X - X_{sr}$, after that, according to formula (19) we calculate its projection and get $KLCoef_{new}$:

$$KLCoef_{new} = {X'_{new}}^T \cdot (X \cdot W) \cdot |C_Y|^{-1/2} \qquad (20)$$

We go through the database by comparing the difference norm for each vector:

$$d(i) = \|KLCoef(i) - KLCoef_{new}\|; \quad i = 1,2 \ldots\ldots M \qquad (21)$$

and where *d(i)* it is minimal we can associate it with a vector or image in the database.

Let's look at some examples of this method. Fig. 4, gives an example of one person with different head positions and analyzed as an entry for said ENT database.

The first person on the right is the closest person according to the Karhunen-Loeve method and continues to line up to the right according to formula (21), ie according to the distance from the input image. So, if we marked the examined image with a_{11} the next one, it would be a_{12} (first on the right), which is also the closest, while the next one a_{22} (second on the right of the examined one) is at a greater distance and so on. Also, let's look at two more interesting examples (Fig.5 and 6).

Fig. 4. Recognition of the human character

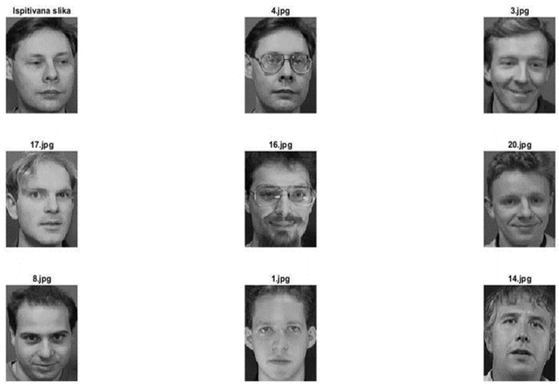

Fig. 5. Recognition of the human character

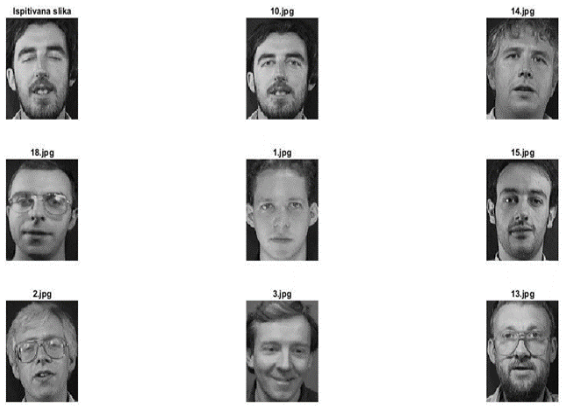

Fig. 6. Recognition of facial expression

Note that in Fig. 4, the examined person with a different position of the person's head to the face in the base mentions that the program will not successfully solve all possible situations, which is why we are talking about the percentage of recognition. More precisely, no software will successfully solve all situations with a probability of 100%. The mentioned percentage of recognition (rate recognition) can be defined as the quotient of successfully resolved cases through their total number expressed as a percentage. In our case, it was 80%. Fig. 5 clearly shows that the program also managed to connect a person when wearing glasses (first right). Also, in Fig. 6, the program successfully associated facial expression with the face of the subject. Of course, the question arises as to whether the probability would be the same on a larger database. The only real and correct answer is future research on much larger databases, as well as a further theoretical elaboration of this method.

7. CONCLUSION

The area of face recognition software is very wide, starting with safety tasks through face recognition of certain persons in the official state database, all to the biometry for various user identification. Of course, the use in analyses with the help of IKT is very important. It is important to mention that this recognition software can be used individually, and with other biometric methods. The importance of the research is in an attempt to increase the percentage of face recognition. With this, the software, using the Karhunen Loeve method, gives the 8 most similar persons and at the end, the operator gives the final word. This approach increases the accuracy of face recognition. Also, the results of this research can be practically implemented with the help of a wider community. The main contribution is the improvement of analysis with the help of IKT and with the face recognition software, but also to point to future possibilities of analyzing with the contribution of ne scientific field: interaction between people and computers.

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