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Mathematical Models Image Face of the Personality

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ABSTRACT: The article examines the task of creating a mathematical model of the system of the image of the person's face. In particular, the contrast algorithms in the image of a person's personality are investigated. The paper presents a mathematical model of a person's image and examines its application to the problem of identifying a person with signs of a person. The paper proposes a way to improve the accuracy of mathematical models and algorithms. All quantitative estimates of the quality of the algorithm are represented by a computational experiment on real data. The developed biometric system of identification of a person by the image of a person is designed to recognize face images invariant to the conditions of illumination, size and perspective with a view to its use in solving applied problems (authorized access, search for a target, search through a photo database).

KEYWORDS: faces, images, methods, algorithm, mathematical modeling.

I. INTRODUCTION

Interest in the tasks of personal identification in the image of a person arose long ago, at the end of the 19th century, as part of the development of forensic methods. With the advent of electronic computers, it was natural to move existing methods into computer image processing programs, however, the researchers encountered a number of difficulties along the way. Under the identification of the image of persons is commonly understood a wide range of tasks, namely, face detection in the image (detection, the primary stage of face identification), searching for a given person among the images of the database of faces (identification), localization of anthropometric features of the face (eye corners, pupil centers, eyebrow contours) , nose, lips and facial contours), recognition of emotions, sex determination and age assessment.

The creation of a mathematical model of the image of a person's personality is characterized by the following circumstances:

First, the automatic localization of the characteristic facial features used in forensic science (the corners of the eyes, the corners of the lips, the points of contiguity of the ears, the tip of the nose, the height of the forehead, the shape of the face) turned out to be poorly formalized and challenging.

Secondly, the modern capabilities of digital imaging tools do not allow for the required spatial resolution (as well as brightness resolution) for automatic determination of point data. These circumstances do not allow the use of existing methods for the identification of persons and require the development of new ones.

Materials and methods of solution. There are a large number of fundamentally different methods to determine the identity of a person by the image of his face. The main criteria for evaluating the methods are the computational complexity of the algorithms and the probability of correct identification.

In the task object, the system must identify the user when he appears last near a certain place. At the same time, a number of requirements are imposed on the identification algorithm:

• low implementation cost compared to the cost of the system object.

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• simplicity of the identification procedure (it is desirable that the identification procedure takes place without any user intervention). Identification of a person by a person is related to methods of biometric identification that most satisfy the set requirements. At the same time, a relatively inexpensive camera, such as a webcam, can act as a face image sensor. With the help of the camera, an image of the user's face can be obtained at any time. Therefore, it can be used both in the mode of initialization of the identification system and in the mode of recognition operation. The camera can be located both in the object itself (built-in, on the case), and outside it (for example, to be mounted on the wall and connected to the object via a wireless protocol).

Modern surveillance cameras allow you to get a color image of 1920x1080 pixels or more with a frequency of about 25-30 frames per second. Such high characteristics give the basis to revise the previously formed approaches the task of identifying the image of persons in systems based on the use of web-cameras of observation [1].

II. FORMULATION OF THE PROBLEM

One of the main parameters determining the quality of the identification of facial images is contrast. Since the identification of facial images can have a complex plot character, it makes it necessary to determine its contrast based on the contrast of individual combinations of facial image elements. In this case, all elements are considered equivalent, and the contrast of each pair of them is calculated by the formula.

$$C_{m,n} = \frac{L_m - L_n}{L_m + L_n} \tag{1}$$

Where $C_{m,n} -$ contrast of combination of two pixels of face images L_m, L_n -, brightness of elements identification face images $m \times n$.

Applying the rule of summation contrasts, calculate a set of values $C_{m,n}$, that determine the perception of each pair of elements to identify face images [2]. By averaging the matrix of local contrasts, we obtain a total contrast. The result can be used as one of the evaluation parameters for the identification of facial images.

When assessing the quality of the image of faces, such concepts as contrast and sharpness are used. The contrast of the entire image or the global contrast.

$$C = z_{\max} - z_{\min}, \tag{1.1}$$

where $z_{\max}, z_{\min} -$ respectively the maximum and minimum brightness of pixels in the image. Local contrast is understood as brightness difference between adjacent fragments background object., $C_i = \left| \; z^{(l)}{}_{\max}, z^{(l)}{}_{\min} \; \right|$ where - $z^{(l)}{}_{\max}, z^{(l)}{}_{\min} -$ maximum and minimum brightness of pixels coinciding with the border of the transition zone between fragments. Relative contrast, $C_{om} = \dfrac{C}{z_m}$, where $z_m -$ highest possible brightness (in most cases $(z_m = 255)$, allows you to determine the possibility and purposefulness of the linear increase in contrast.

Therefore, when assessing contrast, as one of the parameters of the image quality of individuals, it is necessary to take into account a number of features of a person's visual perception. To form this estimate, such image parameters are considered as the arithmetic average of the brightness values. L, the completeness of the use of gradations of brightness, sharpness of the image and its generalized contrast.

For a quantitative assessment of the quality of facial images, the expression may use a complex criterion:

$$Q = k \cdot KC \cdot LQ \cdot KQ \cdot RQ, \tag{2}$$

where $k -$ normalization factor.

There are other complex criteria based on a subjective assessment of the quality of facial images. It is understood that the human operator can determine the importance of individual quality parameters for identifying face images. $Q_1, \ldots. Q_k$ for different classes of distortion. After this, some complex assessment is constructed. Q.

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For example,

$$Q = \alpha Q_1 + \ldots + \alpha_k Q_k$$
$$Q = Q_1^{p_1} \times \ldots \times Q_k^{p_1} \quad (3)$$

Weights $\alpha_1,\ldots,\alpha_k$ or $p_1,\ldots,p_k$ in this case, take into account the relative importance of partial assessments in the integrated quality assessment.

Practice shows choose evaluation criteria for the identification of facial images, as a generalized contrast (K_0) images, one-dimensional image information entropy (H) probability of identification of objects in the image of persons P.

A generalized contrast of facial images can be calculated using the formula:

$$K_0 = \frac{1}{MN}\sum_i \sum_j \frac{\left|L_{ij}^{2y} - L_{cy}^{2y}\right|}{L_{ij}^{2y} + L_{cy}^{2y}} \quad (4)$$

where is the coefficient $y = 1$ corresponds to the linear luminance characteristic (coefficient "gamma"). One-dimensional informational entropy of the image of persons has the form:

$$H = -\sum_{b=0}^{B_{\max}} G(b)\log_2 G(b), \quad (5)$$

Where $B_{\max} = 255 -$ the maximum brightness value of the normalized image of faces corresponding to a gray depth of 8 bits, $G_{(b)} -$ normalized one-dimensional image histogram of image brightness.

The brightness histogram is considered as an estimate of the probability distribution..

$$G(b) = \frac{n_b}{n}, b = \overline{1, l}, p_b \geq 0, \sum_{b=1}^{L} p_b = 1, \quad (6)$$

Where $n_b -$ the number of pixels of the current brightness b (takes values from 1 before l; in the case of a gray scale of 8 bits $(l = 255)$, $n -$ total pixel number of faces, $p_b -$ probability of pixel appearance with brightness b. It is known that an increase in the probability of identifying objects P on the image can be achieved by increasing the resolution R or increasing contrast and reducing noise [5].

$$P = \exp\left[-\left(\frac{B \cdot m}{2R\Delta l\sqrt{D}}\right)^2\right] \quad (7)$$

Where: $B -$ object shape factor; $m -$ scale of shooting, $R -$ resolution, 1/MM; $\Delta l -$ object size, MM; $D -$ the difference between the optical densities of the object and background.

You can put the shape factor of the object $B = 1$ (a circle), and the scale of shooting in the conditions of closed receiving systems $m = 1$. Magnitude $R\Delta l$ for digital images just equal to the characteristic object size d in pixels.

$$P = \exp\left(-\frac{1}{4d^2 D}\right) \quad (8)$$

Instead of the optical density of photographic images for digital images, you can enter a similar definition. D, as a function of local contrast C:

$$D = \log_2 \frac{1}{1-C}, \quad (9)$$

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where $C = 1 - \frac{B_{fon}}{B_{object}} -$ local contrast, B_{fon} и B_{object} - the brightness of the background and the object, respectively, in the neighborhood of the border between them.

For images, when the number of dark and light areas are approximately equally used, Michelson's contrast is determined by the ratio [6]:

$$C = (I_{\max} - I_{\min})/(I_{\max} + I_{\min}) \tag{10}$$

where $I_{\min}$ and $I_{\max}$- respectively, the minimum and maximum values of brightness in the analyzed area of the image, and in the denominator is twice the average brightness [3].

A common mechanism for determining contrast is RMS contrast, which is applied to all image types and is determined by the formula:

$$C = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(I_i - \bar{I})}, \quad \bar{I} = \frac{1}{n}\sum_{i=1}^{n} I_i, \tag{11}$$

where $I_i -$ brightness $i -$ pixel area for which the contrast is estimated. The main disadvantage of this definition is its low performance compared to the contrast between Weber and Michelson. Analysis of relations (9) (10) (11) shows that the probability of recognizing an object in an image depends on the local contrast. In turn, the sharper the boundary of the object and the lower the noise level in the image, the higher the contrast [7,8]. There is an image in grayscale $I^F{}_{i,j}$, containing face area: $I^F = \{I^F{}_{i,j}, i = 1, N^F; j = 1, M^F\}$ Denote by variables $x, y -$ coordinates of the upper left corner of the rectangular area in the image, $a, w, h -$ corresponding to the width and height of the area. Suppose that the coordinates of rectangular areas describing the eyes in the image of the left and right eyes, respectively, are also found $E^1 = \{x^1, y^1, w^1, h^1\}$, $E^r = \{x^r, y^r, w^r, h^r\}$. Denote the inter-eye distance equal to $h^e = x^r - x^1$. Then the coordinates $F^* = \{x^{f*}, y^{f*}, w^{f*}, h^{f*}\}$ refined image of the face in the original image I^F will be equal:

$$x^{f*} = x^1 - h^e * K_x{}^e,$$

$$y^{f*} = y^1 - h^e * K_y{}^e,$$

$$w^{f*} = x^r + h^e * K_w{}^e,$$

$$h^{f*} = y^r - h^r + h^e * K_h^e, \tag{12}$$

Here $K_{x^e}, K_{y^e}, K_{w^e}, K_{h^e}$ – empirically derived scaling factors. Next, the resulting face area is divided into zones of interest, each of which is subjected to successive operations of scaling, contrasting and aligning histograms in the same way. Next, we build refined and scaled according to the standard size $[N^{f*}, M^{f*}]$ image of face zones I^{F*}. In this method, the signs that determine the degree of similarity of the test image with each image of a known sample is a set of values $\{C\} = \{C_{ij}, i = 1, N; j = 1, M\}$, where $N -$ number of classes, $M -$ the number of class samples in the training set. For calculation, the standard normalized cross - correlation formula is used (13).

$$C_{u,v} = \frac{\sum x, y\{[Ix, y - \overline{I(u,y)}] * [T(x-u, y-v) - \overline{T}]\}}{\sqrt{\sum x, y[I(x,y) - \overline{I(u,v)}]^2 * \sum x, y[T(x-u, y-v) - \overline{T}]^2}} \tag{13}$$

where $I(x, y) -$ input image resolution $N^I * M^I$ pixels, $T(x, y) -$ resolution template $N^T * M^T$ pixels, $\overline{T} -$ pattern average, $\overline{I(u,v)} -$ the average of the image input section under the template, $u, v -$ bypass coordinates by image $u = 1, (N^I - N^T + 1)$; u=1,(N^I-N^T+1); $v = 1,\ M - M^T + 1$. The resulting correlation [3-4] value for a given

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image is calculated as the absolute maximum over all u и v. To improve the quality of recognition, we use the accumulation of correlation peaks for K last measurements [9-10]. So for each k detected face will be calculated $C_{i,j}^{\max}$ according to the formula:

$$C_{i,j}^{\max} = \max_{k} C_{i,j}^{k} \tag{14}$$

Another approach is to accumulate the definition of the mean correlation over K last measurements. Then for everyone k detected face, will be calculated $\overline{C_{i,j}}$ according to the following formula:

$$\overline{C_{i,j}} = \frac{1}{k}\sum_{k=1}^{k} C_{i,j}^{k} \tag{15}$$

Such an approach (13), (14), (15) to the formula allows to improve the recognition, without requiring a fixed fixation of the operator in front of the camera. Moreover, accumulation can significantly improve the quality of recognition in the case of different face positions in the sequence K last frames [4].

III. EXPERIMENTAL RESULTS

The developed software (software) was tested on an Intel compatible computer running Microsoft Windows Vista Home Premium. The software (software) supports video sources with a resolution of only 640x480 pixels. The cameras used as the source must support Direct Show and the ability to set the RGB 640x480x24 or RGB 640x480x32 mode

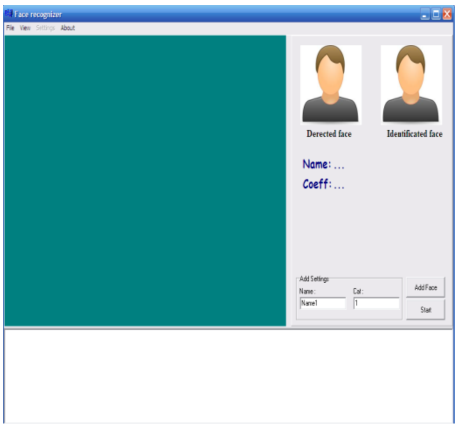


Fig.1 Main window interface software

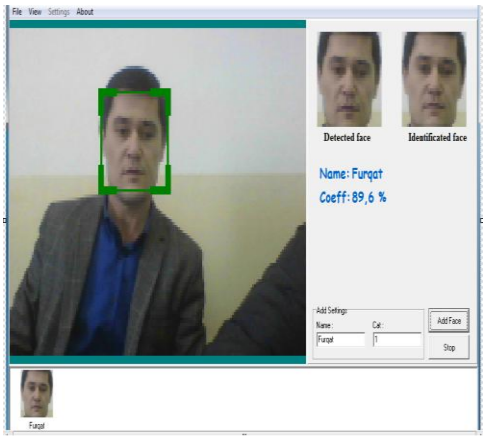
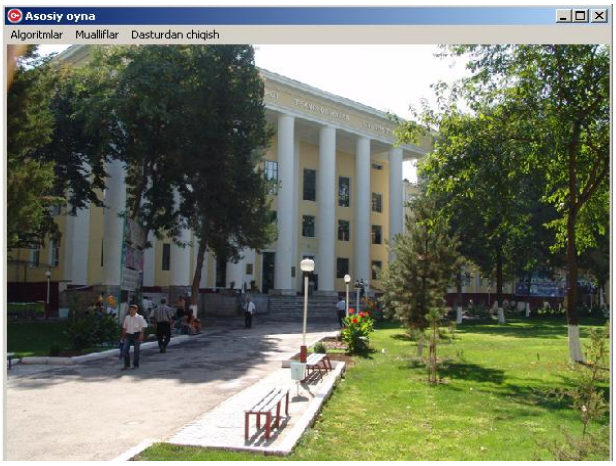


Fig. 2 Webcam snapshots highlighting face images

If you need to add a user, you must click the "Add face" button in the demonstration window (Fig. 2.). The name of the training set to which the user should be added will be requested. You can either select a selection from the list (by double clicking on the name of the selection), or enter a new name. In the latter case, a new training set will be automatically created. The system will enter the standby mode for 5 seconds, after which the process of accumulating frames of the face will begin within 40 seconds (Fig. 3)

Fig. 3 Teaching facial image of the person's face

A training sample of 5 face images of 5 people (5x22 face images) was formed. Each image was subjected to pre-processing by converting to grayscale, aligning histograms, contrasting and scaling up to 128 x 128 pixels for the algorithm and 48x48, 32 x32 pixels for different areas of interest of the correlation method (Fig. 4).



a)

Interface programs

b) Comparison of the face with signs

Fig. 4 Search base with signs of identification of the image of the person's face

The training sample was built 110 eigenvectors. Then the sample was decomposed into these vectors, and the resulting eigenvalue values analyzed. To do this, it was calculated by the formula (6), (8), (10), (11), (12) and the minimum distance by the formula (13), (14), (15). The results for the Furqat sample class are presented in (Fig.4). It can be seen that by the minimum distance to other classes, only the first 4 eigen values (features) make a significant contribution; by the standard deviation of the 50% interval, the first 3 eigenvalues fall into (Fig. 5). However, taking into account the similar data of the other classes, the only sign of a 50% hit the 50% interval [5].

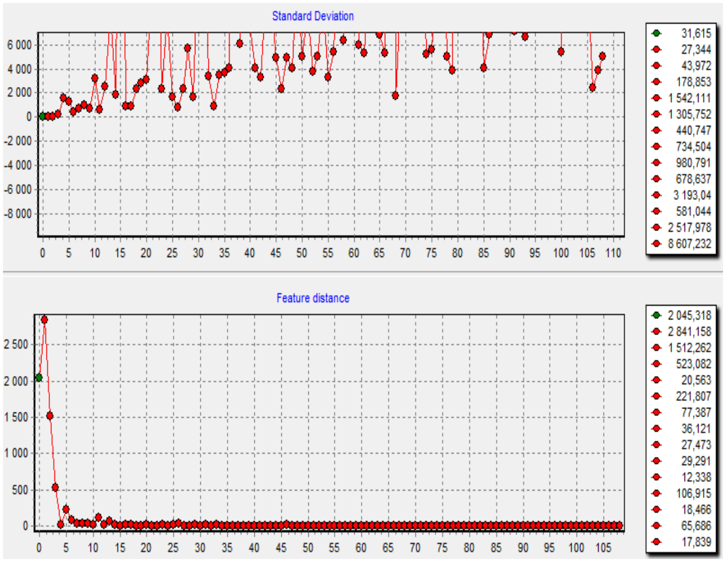


Fig.5. Characteristic distances for object feature class

Testing was conducted on 6 zones in the face: a rectangular area of the eyes, separate zones for each eye, nose, mouth, and the whole image of the face. Similar tests with similar results were carried out for expansions in a substantially larger and smaller number of eigenvectors. This made it possible to conclude that this method is not very suitable for constructing signs in real conditions of the presence of geometric distortions and instability of the illumination of the identification of persons, despite the high speed. For those present in the training set, the results are presented in table 1.

Table 1. Recognition results for the person presented in the database

Name personalities	Number positives	Number of denied access	Number of errors recognition	Successful Identification Percentage
Furqatbek	193	1	0	90.5
Ravshan	187	0	0	88.3
Sardor	175	41	0	89.6
Hurshid	112	9	0	76.6
Jasur	91	9	0	80.3

Successful Identification Percentage: 92.8%
Recognition errors: 0.0%
Access denied: 7.2%

Here, the number of operations is the number of times the system has issued information about the successful user identification of a successful identity recognition; the number of access denials is the number of frames for which a person was detected, but could not be assigned, to any of the classes; the number of errors is the number of times the user has been mistakenly identified as another person from the database. Table 2 presents the identification results for unauthorized persons.

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Table 2. Recognition results for persons missing in the database

Name	Number positives	The number of errors in statistics	Number of failures in access	Percent mistakes
Ranshan	0	0	61	0
Sardor	0	0	173	0
Hurshid	0	0	55	0
Jasur	10	0	205	4.7

Recognition errors: 4.7%
Wrong access permissions: 0.0

Here, the number of operations - the number of times the erroneous detection of an outsider as a user from the database number of errors according to statistics - the number of times when a user was mistakenly admitted to the system as another person from the database (the number of erroneous detections reached the number of accumulated results required for making decisions). The number of denied access is the number of frames on which a person was detected, but could not be assigned, to any of the classes. From the results it can be seen that, despite the erroneous alarms that have been made, due to statistical processing, access to the system was closed in all cases. The source material is a raster image (the linear size of the face image is not less than 150x100 pixels, not more than 1000x800 pixels). Scale transformations relative to the standard - decrease / increase by 6 times. The variation of illumination is in the range of 10–15% of the average level of brightness of the reference image. Description invariant to the background. Support many standards (beard / no beard, glasses / no glasses). The probability of the appearance of the desired photo in the top five of the rating (with a base of 500 standards) is ~ 97%. Description formation time ~ 1 c. The comparison time is ~ 3 s (for a base of 5,000 people)[6-7].

IV. CONCLUSION AND FUTURE WORK

In conclusion, it should be noted that the developed software, oriented to assess the process of identifying a person's face, allows to increase the efficiency and effectiveness of the workflow. The images were matrix, and pixel software was developed, which gives the elements of the matrix the color of their values. Improved system for identifying objects from the database (DB) based on facial signals.

The practical significance of the study lies in the fact that the proposed software algorithms can be used to design face image processing systems and parts that are a component of modern modeling systems for identifying and comparing face recognition identifiers.

The stages of designing the development of a new algorithm for identifying face images in the process of forming a mathematical model of an identification algorithm for face images of a person are defined. The significance of the research results is due to the promising development of the theoretical foundations of the personality, which identify the biometric technologies of the system of identification of images of a person’s face.

The reliability of the research results is confirmed by a positive comparison of face recognition and face identification, rational correct use of mathematical statistical methods and algorithms when applying a mathematical model, as well as comparison of experimental studies on algorithms based on model and practice. Based on the results of the study, the detection efficiency of individuals by the pixel intensity of experimental surveillance cameras based on the person’s face was increased.

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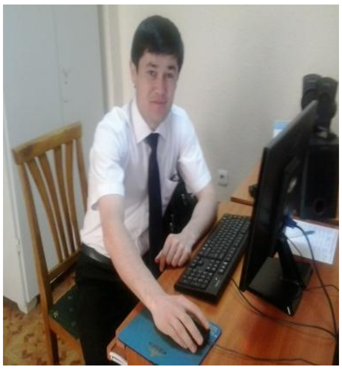

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