

Models and Methods for Solving Face Recognition Problem by Photos

Farit Gabdiev
Ufa State Aviation Technical University
Ufa, Russia
faritgabdiev@mail.ru

Nafisa Yusupova
Ufa State Aviation Technical University
Ufa, Russia
yussupova@ugatu.ac.ru

Olga Smetanina
Ufa State Aviation Technical University
Ufa, Russia
smoljushka@mail.ru

Ekaterina Sazonova
Ufa State Aviation Technical University
Ufa, Russia
rassadnikova_ekaterina@mail.ru

Abstract—Automatic detection and detection technologies are widely used in different areas. This article contains analysis of a face recognition problem, description of the problem, mathematical formulation of the problem, analysis of methods for solving it, proposed approach, and the results of the experiment. The proposed approach to solving the problem as a set of methods (i.e., histogram equalization; color image segmentation in RGB color space based on color saliency; measure distances between markers attached to facial landmarks; nearest neighbor algorithm) implemented at different steps assures a positive result. The results obtained in the course of experimental studies allow us to conclude that the developed software based on the above methods also provides a positive result.

Keywords—face recognition, face detection, intelligent technology, histogram equalization; color image segmentation

I. INTRODUCTION

Nowadays, there is an increased scientific interest in face recognition. Popularity is associated with numerous practical needs and development trends in the field of automatic recognition. Automatic detection and recognition technologies are widely used in the following areas: modern security and door phone systems; e-commerce; forensic examinations; computer animation, etc.

Research and practical development are carried out by many researchers and companies.

There are numerous studies in this area and ready-made IT-solutions, development of information technologies and artificial intelligence technologies allow to improve the quality and speed of data processing.

Authors of this article consider the current state of the problem of pattern recognition, including the general statement of the problem and task of face recognition by photos. Also, authors of this article discuss statement of the face recognition tasks, methods for solution of these tasks, the choice of identification method to improve recognition quality, the issues of practical implementation.

II. THE STATE OF THE ART

When solving the pattern recognition problem, classification of objects of different nature is carried out based on precedents taken as a sample.

If objects have some characteristics that are part of one class, then these objects should be similar by some criterion.

Then pattern recognition problem can be formulated through concepts such as objects and their representation, classes and their characteristics, the algorithm as the decision rule that allows to get the result in the form of affiliation to the criteria classes (Table I). [1,2]

Examples of objects taking into account their nature and solved tasks are presented on Figure 1 [3]. Thus objects can be represented directly by an object (object, person), situation, system.

Depending on the way of object representation, there are the following recognition types: character recognition (letters or numbers recognition), speech, electrocardiograms, circuits, recognition faces by photo, gestures, machine vision, image through the camera and its symbolic description), x-ray, set of signs, etc.

Analysis results of methods and approaches for the classification indicate that they include the following methods: Bayesian approach, based on the statistical nature of the observations, linear classifier (Perceptron Learning Algorithm), optimal separating hyperplane, nonlinear classifier (Multilayer Perceptron), Potential Function Methods, Method of committees for recognition problems, classification based on reference comparison, and context-sensitive classification technique [4].

The solving pattern recognition problems is characteristic of many areas and may be part of a more general problem. For example, face recognition problem can be used for passport control procedures in the airport, entrance control system in the enterprise, security system in crowded places, bank card verification, forensics, etc. In addition to direct face recognition by photo it is possible to evaluate emotions, recognize faces by video stream, etc.

Let us consider some practical application of ready-made recognition systems through their various aspects:

- from the widespread and growing global market for face recognition technologies to the ban on using such systems (several US cities). This ban is justified by the statement: “face recognition systems is contrary to human rights and threatens to abuse by law enforcement agencies” [5];

- from the implementation success of face recognition systems depending on the algorithm and its speed, the database of standards to a decrease in recognition quality, which depends on changing the head angle, reducing light, etc.

The further emergence of ever new practical solutions is due to the development of information technologies and artificial intelligence technologies.

Among the most famous face recognition services by photo, there are Search Face («VKontakte»), FindFace (NtechLab), Google and VisionLabs, Face API (MicroSoft), Pictriv, etc. (Fig. 2).

Face recognition services have supporters and opponents. Recognition technologies have great practical significance because systems are based on such technologies.

Currently, there are many software applications that have been developed in this area (Table. II).

TABLE I. ANALYSIS OF PATTERN RECOGNITION PROBLEM

Given:				
1. Objects	2. Characteristics of the object	3. Criteria	4. Classes	5. Characteristics of the class
Set X	$x_j(h_{j1}, h_{j2}, \dots, h_{js}), j=1, \dots, R; h_{ji} - i$ -th element characteristics of the object $x_j, i=1, \dots, s$.	k_1, \dots, k_m	$X_1, \dots, X_n, i=1, \dots, n$	$I_{X_i}(X_1, \dots, X_n)$
Special aspects of private problem statements:	The nature of the objects and method of formalization (presentation)	Similarity with the sample and others	The number of classes and the relationship between classes	The ways to configure characteristics of the class and relationship with X
Find out:				
Algorithm A is defined on X	The result should be obtained for each object $x_j \in X$ as belonging to class $X_i (i \in N)$ with taking into account criteria and using the algorithm A and information $I_{X_i}(X_1, \dots, X_n)$.			
Special aspects of problem statements	Heuristic and formal requirements for the algorithm and restrictions on all types of information			



Medical diagnostics

Examples of objects: the set of all people suffering from a certain disease.

Algorithm: Develop the decisive rule allowing to attribute the patient to one of the groups. This solution should be worked out on the material of examined patients with verified diagnosis.



Technical diagnostics

Examples of objects: the set of failures of a complex technical system represented by indirect symptoms.

Algorithm: Define the decisive rule that allows to find the malfunction type by the set of tests and indirect signs.



Classification and diagnosis of situations

Examples of objects: the set of types of situations for people, i.e., technological process control.

Algorithm: Find the solution prepared in advance for the specific type of situation.



Classification in sociology

Examples of objects: the set of people defined by certain characteristics.

Algorithm: Find the decisive rule that allows to define the type of representatives by the set of tests and signs.



Typology of systems

Examples of objects: the set of complex systems with certain characteristics.

Algorithm: Divide into homogeneous groups with the representatives selection in each group.

Fig. 1. Examples of objects

Search Face («VKontakte»)	<ul style="list-style-type: none"> • This service allows to find photos on Internet by user's photo [6].
FindFace (NtechLab)	<ul style="list-style-type: none"> • This service allows to find photos on Internet by user's photo. • This service allows to identify a person in a stream of many thousands [7].
VisionLabs	<ul style="list-style-type: none"> • The payment function used is based on scanning the buyer face at the checkout [5].
Face API (Microsoft)	<ul style="list-style-type: none"> • This service allows to detect and compare human faces. • This service allows to organize images into groups based on similarities. • This service allows to identify previously tagged people in images [8].
Google	<ul style="list-style-type: none"> • This is image search service. • This service can be used for face recognition by photo [9].
Pictriv	<ul style="list-style-type: none"> • This is face recognition search service [10].

Fig. 2. Famous face recognition services

TABLE II. SOFTWARE APPLICATIONS OF FACE RECOGNITION

SoftwareName / Criteria	Face-Intellect	Digikam	Face Morpher WebEdition	KLIK	VOCORD FaceControl	VeriLookStandart SDK Trial
Identification accuracy	95,6%	?	-	91,3%	>90%	?
Face detection	+	+	+	+	+	+
Face identification	+	+	-	+	+	+
Application Restrictions	Installed system «Intellect»	-	-	Facebook account, smartphone	VOCORD videocameras	Having a stable Internet

Despite widespread use of face recognition technologies, theoretical developments are relevant because they allow to improve the recognition quality and speed.

The solvability of the problem of face recognition by photos was proved by a series of successful works that showed the possibility of technical implementation and economic benefit [10-27]. The general questions of pattern recognition are studied in the works of R.O. Duda, P.Ye. Hart, P. Viola, M. Jones, Tuj., Gonzales, R., Bui thi Thu Chang, A.A. Druki, V.I. Vasilyev, A.L. Gorelik, V.A. Skripkin, Yu. Barabash, L.T. Kuzin, F.I. Peregudov, F.P. Tarasenko, E.E. Temnikov, P. Winston, K. Fu, Y.Z. Tsyppin, et al. Analysis of theoretical works on face recognition has shown a wide variety of aspects in solving problems, making hypotheses, solving techniques, considering the different tasks, applied methods etc. (Table III).

Despite numerous studies in face recognition, using a complex of methods can improve the accuracy of solving a problem, considering existing distortions in the image and / or additional items.

This article considers the current state of the pattern recognition problem including general statement of this problem, face recognition by photo, in particular, the statement of the face recognition problem and solving methodology, choice of identification method to improve recognition quality, and issues of practical implementation.

III. THE STATEMENT OF THE PROBLEM

We propose to develop an approach to solve the problem of face recognition by photo as a complex of methods and to conduct an experiment on a set of images obtained as a result of distortion (turns, foreign objects). The formulation of the general task of the research is presented as follows: based on the analysis of the initial data presented by different photos in a reasonable time and automatically give one of the following answers: 1) there is no face on photo; 2) the face on this photo is the face from our collection; 3) there is a face on photo, but it is not in the collection (in this case, you can add it to the collection).

TABLE III. PATTERN RECOGNITION RESEARCH OVERVIEW

Authors	The state of the art			
	Task / Subtask	Approach	Methods	Special aspects of recognition task
E.L. Stolov A.V. Shlynikov.	Two photos of the same person are compared.	The mutual arrangement analysis of the brightest image areas is performed. The artificial combination of angles is performed when comparing two photos of the same person from different angles.	Wavelet transform highlights the brightest areas for combined images. The converted image is replaced by the compressed image based on Fourier transform. The transform coefficients are compared.	-
A. I. Sherstobitov V. P. Fedosov V. A. Prikhodchenko M. V. Timofeev	Group photo is processed by face recognition.	Modifications of face recognition method are based on principal component analysis, namely the use of pre-separation algorithms of images into background and objects (faces).	Principal component analysis is used. This algorithm allows to structure information in the processing of facial images. Also, this algorithm allows searching and grouping of photos by specified person.	Face test image database sets (ORL, BioID) and a randomly generated set of group photos are used to evaluate effectiveness.
Z. Li Stan, K. Jain Anil	Face recognition is performed in space.	A range of concepts, methods and algorithms are used by automated systems for detecting and recognizing faces, namely local representation of facial features and face alignment model.	-	Comprehensive coverage of detection, tracking, alignment, feature extraction and face recognition technologies is considered.
P. Viola M. J. Jones	Face recognition is performed by photo.	Machine learning is used for visual objects detection.	The Learning Algorithm is based on AdaBoost. The algorithm selects a small number of critical visual functions from a larger set and provides effective classifiers. The combining complex classifiers method into a "cascade" is shown. This method is an object-oriented mechanism for focusing. It discards background areas of an image at a fast speed and spends more computation on promising object-like areas.	The concept of "integrated image" is considered.
Yu. V. Vizilter V. S. Gorbatshevich A. V. Vorotnikov N. A. Kostromov,	Biometric template is built to identify faces.	Convolutional neural network training is performed. Hash conversion is performed using Hashed Forest Method. The generalization of Boosted Similarity Sensitive Coding (SSC) method is used for solving the problem of constructing an optimal hash taking into account the tasks specifics of person identification and verification.	Convolutional Neural Network and Hashed Forest are used.	-
G. Wexler	Face recognition is performed by photo taking into account emerging problems.	-	The following technologies are used: Neural Networks, Statistical methods, Signal and Image Processing, Computer vision, Machine Learning, Pattern recognition.	The following special aspects are considered: cluttered environment, image variability, occlusion and disguise, temporary changes as part of open dialing recognition, evolution and prospects of facial recognition research.

Authors	The state of the art			
	Task / Subtask	Approach	Methods	Special aspects of recognition task
A. Levin D. Lischinski Y. Weiss	Interactive digital matting is used for face recognition. The extraction process of foreground image objects is performed based on limited user input.	The value function is extracted from local smoothing for the foreground and background colors. In the resulting expression, the foreground and background colors can be analytically excluded to obtain a quadratic value function in alpha-range. The search global optimum alpha matte matrix occurs by solving a sparse linear system of equations.	The algorithm by P. Viola and M.J. Jones and the demographic classifier taking into account aspects such as gender and ethical background.	The foreground opacity, the foreground and background color are evaluated in each pixel.
A.V. Morgunov D. A. Mansurova K. A. Tyurin	Face recognition problem is described	The approach is based on Eigenfaces and Fisherfaces algorithms.	Eigenfaces algorithm maximizes overall scatter. This can lead to a problem when the dispersion is generated from an external source. Components that have maximum dispersion in all classes are not necessarily useful for classifying an object. Linear Discriminant Analysis with optimization (Fisherfaces algorithm) is used to save clear information.	The data is displayed as a vector in the multidimensional image space. The most accurate results were obtained using methods and algorithms based on deep learning and neural networks.
G. Shakhnarovich P. Viola T. Darrell	Face Recognition and Posture Assessment are performed.	The approach is based on using Locality-Sensitive Hashing.	The algorithm extends the Locality-Sensitive Hashing method which finds close neighborhood in time. They are sublinear in a number of examples.	Experiments show that the resulting algorithm is sensitive to hashing parameters. The algorithm allows to quickly and accurately evaluate the pose of human figures from the very large database of sample images.
W. Wang J. Yang, J. Xiao, S. Li, D. Zhou	Face recognition is performed by photo.	The approach is based on using deep learning method to achieve facial detection and unlimited facial recognition.	Layer learning method of deep convolutional neural network is used. Transformation method of sample is used to avoid redefinition.	-

Mathematical statement of the problem of face recognition by photo formulated in the following way: Given: matrix $A(m \times n)$ pixels in RGB color space; set of objects (a collection of photos with faces) $O = \{o_1, o_2, o_3, \dots, o_k\}$, where $o_i = \langle x_{i1}, x_{i2}, \dots, x_{il} \rangle$ - feature vector (distance between points of interest).

Task: Find recognition function F'' whose output determines the belonging of the incoming matrix (after its mapping into the feature vector w) to the set of objects

$O - F': A \rightarrow w; F'' = 1$, if $\sqrt{\frac{1}{l} \sum_{i=1}^l (w - o_i)^2} < \varepsilon$ and $F'' = 0$,

if $\sqrt{\frac{1}{l} \sum_{i=1}^l (w - o_i)^2} \geq \varepsilon$, where standard deviation $\varepsilon = 1$.

The recognition function can be constructed by different methods. We need to choose a method that allows to increase recognition quality.

IV. SOLVING TECHNIQUE FOR FACE RECOGNITION PROBLEM

Technique of solving the problem (Fig. 3) consists of five steps. The first two steps are aimed to prepare the data for analysis. The search for points of interest, further finding the distances between them and their relations is performed to

detect facial features. The final step in the task of face recognition in photo-based methodology is the process of identification. In this step, the points of interest depicted on photo obtained in the previous steps are classified.

The following set of methods is used when implementing the approach: in the second step - histogram equalization method (has the ability to perform fully automatic and does not require additional settings); in the third step - color image segmentation in RGB color space based on color saliency when performing face identification; measure distances between markers attached to facial landmarks when detecting facial features; in step 4, the nearest neighbor algorithm. To implement the approach, we utilise a software using C# programming language developed in the framework of the study. The computational experiment uses a set of 30 photos obtained as a result of distortion of the collection (turns, foreign objects) is used.

V. RESEARCH RESULT

The results obtained in the course of experimental studies allow us to conclude that the developed software based on the above methods gives a positive result. The addition of a pre-processing step to the technique, i.e., the use of the histogram

equalization method, can significantly improve the quality of recognition. There may be some errors in complicated datasets that can be detected only under experimental conditions.

The software implementation of the approach demonstrates the resistance to horizontal and vertical rotation

of the image at the angles of 10 and 5 degrees, respectively. Certain problems arise when applying various foreign objects on the face (glasses, mustache, bruises).

Comparison of common methods of training convolutional neural networks is shown in tabular form (Table IV).

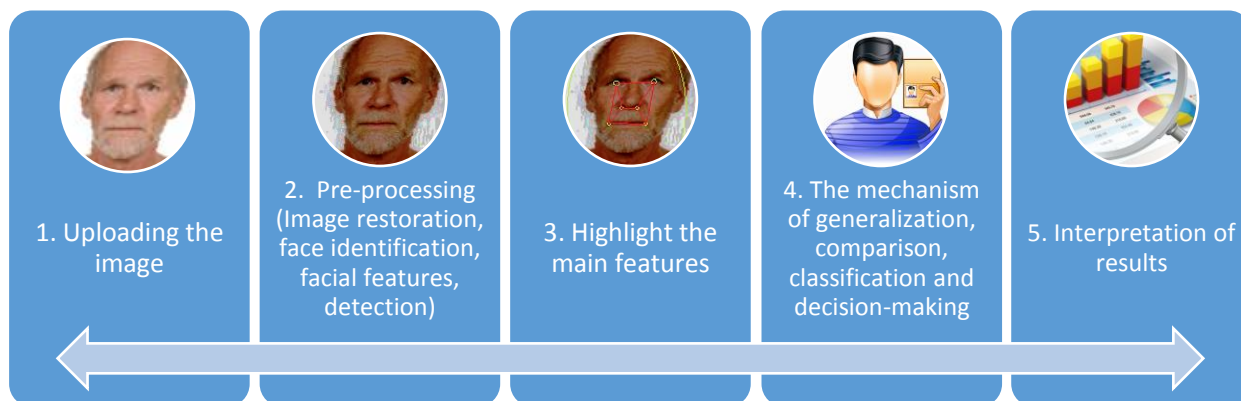


Fig. 3. Solution structure

TABLE IV. COMPARISON OF COMMON METHODS OF TRAINING CONVOLUTIONAL NEURAL NETWORKS

Name	Accuracy	Advantages	Disadvantages
RMSprop	83%	can solve nonstationary problems.	-
Adagrad	81%	no need to select the speed of learning accurately	the sum of squares of updates can increase as much as needed which can lead to paralysis of the algorithm
Adadelta	73%	unlike Adagrad, the sum of the gradients is replaced by the exponentially decaying average of the squares of the gradients obtained in the previous steps	-
Adam	76%	the method combines the advantages of two methods: the ability of AdaGrad to cope with sparse gradients and the ability of RMSProp to solve nonstationary problems.	-
SGD	78%	<ul style="list-style-type: none"> easily implemented; the loss function and list of algorithms can be any (if the loss function is not differentiable, it can be approximated differentiable); easy to add regularization; streaming training is possible; suitable for tasks with big data; sometimes you can get a solution without even processing the entire sample. 	there is no universal set of heuristics, they need to be selected for a specific task separately

VI. CONCLUSION

Automatic detection and detection technologies are widely used in different areas. Despite a number of works existing in the field of face recognition, using a set of methods can improve the accuracy of solutions, considering existing distortions in the image and / or additional items.

The proposed approach to solving the problem in the form of a set of methods (histogram equalization; color image segmentation in RGB color space based on color saliency; measure distances between markers attached to facial landmarks; nearest neighbor algorithm) implemented at different steps of the solution gives a positive result. The addition of a pre-processing step to the technique, i.e., the use of the histogram equalization method, can significantly improve the quality of recognition. There may be some errors in complicated datasets that can be detected only under experimental conditions.

The software implementation of the approach demonstrates the resistance to horizontal and vertical rotation of the image at the angles of 10 and 5 degrees, respectively. Some problems arise when applying various foreign objects on the face (glasses, mustache, bruises).

The authors propose using of the method of potential functions for solving the problem of photo image classification.

ACKNOWLEDGMENT

The results of the research presented in this article were supported by Grants RFBR 19-07-00709 and 18-07-00193.

REFERENCES

- [1] Yu. I. Zhuravlev, "Selected scientific works" [Izbrannye nauchnye trudy], Moscow, 1998, P. 416 (in Russian).
- [2] Yu. I. Zhuravlev, S. V. Ablameyko, A. S. Biryukov et al., "Algorithms for algebraic and logical correction and their applications" in Pattern Recognition and Image Analysis, vol. 20 (2), 2010, pp. 105-117.
- [3] V. I. D. Mazurov, "Mathematical methods for pattern recognition" [Matematicheskie metody raspoznavaniya obrazov], Yekaterinburg, 2010, P. 101, URL: <http://elar.urfu.ru/bitstream/10995/31603/1/mazurov-2010.pdf> (in Russian).
- [4] L. M. Mestetsky, "Mathematical methods of pattern recognition: lecture course" [Matematicheskie metody raspoznavaniya obrazov: kurs lekcij], Moscow, 2008, P. 108 (in Russian).
- [5] "TAdviser. Government. Business. IT.", URL: <http://www.tadviser.ru/index.php> (in Russian).
- [6] "SearchFace - new service for searching people in VK by photo" [SearchFace — novyy servis dlya poiska lyudej v VK po foto], URL: https://www.iguides.ru/main/other/searchface_novyy_servis_dlya_poiska_lyudej_v_vk_po_foto/ (in Russian).
- [7] "FINDFACE of face recognition" [FINDFACE — raspoznavanie lic], URL: <https://findface.pro/> (in Russian).
- [8] Face API — Facial Recognition Software, URL: <https://azure.microsoft.com/en-gb/services/cognitive-services/face>.
- [9] Images-google, URL: <https://images.google.com>.
- [10] Pictriev Service, URL: <http://www.pictriev.com/?lang=ru>.
- [11] A. D. Lopatina, "Face detection based on combination of color and brightness segmentation" [Vydelenie oblasti lica s pomoshch'yu kombinacii metodov cvetovoj i yarkostnoj segmentacii] in Vestnik USATU, vol. 13, 2009, №2(35), URL: [http://www.ugatu.ac.ru/publish/vu/stat/ugatu-2009-2\(35\)/24.pdf](http://www.ugatu.ac.ru/publish/vu/stat/ugatu-2009-2(35)/24.pdf) (in Russian).
- [12] P. V. Bazanov, O. V. Djosan, "Methods of face feature extraction of the human identification problem" [Vydelenie informativnyh priznakov na izobrazhenii lica v zadache identifikacii cheloveka] in Siberian J. of Numer. Mathematics, vol. 9, 2006, № 3, pp. 207-214, URL: <http://www.mathnet.ru/links/ac56a3eaea0818cd2dfa0de6a5c1382e/sjvm114.pdf> (in Russian).
- [13] A. A. Druki, "The face detection algorithms on static RGB images and in video stream" [Algoritmy vydeleniya lic na staticheskikh rgb izobrazheniyah i v videopotoke] in Tomsk State University Journal of Control and Computer Science, vol.320, 2012, № 5, pp.65-69(in Russian).
- [14] R. C. Gonzalez, R. E. Woods, Digital Image Processing: third edition, Pearson Education, 2008, P. 977.
- [15] M. Naeem, I. Qureshi, F. Azam, "Face recognition techniques and approaches: a survey", URL: https://www.researchgate.net/publication/281838833_FACE_RECOGNITION_techniques_and_approaches_a_survey
- [16] Neeti Jain, Nagesh Sharma, Nishant Kamboj, Ankur Kakani "Analysis of Different Methods for Face Recognition" in International Journal of Innovative Computer Science & Engineering, vol. 1(2), pp. 18-21.
- [17] E. L. Stolov, A. V. Shlynikov, "Recognition face in picture by means of analysis of special regions" [Raspoznavanie lic na fotografii putem analiza harakternyh oblastej] in Lobachevskii Journal of Mathematics, vol. 149(2), 2007, pp. 138-145 (in Russian).
- [18] A. I. Sherstobitov, V. P. Fedosov, V. A. Prihodchenko, D. V. Timofeev "Face recognition on groups photos with using segmentation algorithms" [Raspoznavanie lic na gruppovykh fotografiyakh s ispolzovaniem algoritmov segmentacii] in Izvestiya SFedU. Engineering Sciences, vol. 13, 2013, pp. 66-73(in Russian).
- [19] Z. Li Stan, K. Jain. Anil, Handbook of Face Recognition: Second Edition, Springer, 2011, P. 699.
- [20] Yu. V. Vizilter, V. S. Gorbatshevich, A. V. Vorotnikov, N. A. Kostromov, "Real-time face identification via cnn and boosted hashing forest" [Identifikaciya lic v realnom vremeni s ispolzovaniem svyaznoy seti i heshiruyushchego lesa] in Computer Optics, vol. 41, № 2, 2017, pp. 254- 265 (in Russian).
- [21] Wexler G., "Reliable face recognition methods. Development, implementation and evaluation of the system" [Nadezhnye metody raspoznavaniya lic. Razrabotka, vnedrenie i ocenka sistemy], 2007 (in Russian).
- [22] P. Viola, M. J. Jones, "Rapid object detection using a boosted cascade of simple features" in IEEE Conf. on Computer Vision and Pattern Recognition, 2001, vol. 1, pp. 511-518.
- [23] M Jones, P Viola, "Fast multi-view face detection" in Mitsubishi Electric Research Lab TR-20003-96, vol. 3, №14, 2003.
- [24] G. Shakhnarovich, P. Viola, T. Darrell, "Fast pose estimation with parameter sensitive hashing" in Proceedings of the Ninth IEEE International Conference on Computer Vision, vol. 2, 2003, pp. 750-757.
- [25] A. Levin, D. Lischinski, Y. Weiss "A closed form solution to natural image matting" in Proceedings of IEEE CVPR, 2006, pp. 277-302.
- [26] A. V. Morgunov, D. A. Mansurova, K. A. Tyurin A.B., "Face recognition: a problem and a solution" [Problema raspoznavaniya lic. Obzor metodov ee resheniya] in International scientific-practical conference Issues of Technical and Physical and Mathematical Sciences in the term of Modern Researches, № 4(3), 2017, pp. 58-70 (in Russian).
- [27] W. Wang, J. Yang, J. Xiao, S. Li, D. Zhou, "Face recognition based on deep learning" in Book: Human Centered Computing, 2015, pp. 812-820.