Enhancement of Information Technology for Person Identification Based on Image Quality Features

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Abstract

This paper devoted the research with an aim of enhancement of information technology for person identification based on image quality features.

Nowadays, face recognition and identification technologies are rapidly spread and widely used in various fields, from access control of sensitive data to building war crime cases. So, it is critically important to investigate such technologies, so that mistakes made by the software or those using it could not have an impact on human lives by dire consequences.

Due to the previous research, it was found out that the accuracy rate of the algorithm applied for face recognition and identification can significantly vary on different datasets. It is common that databases of different organizations contain images of different quality. Comparison of the high-quality image (such as passport image in law enforcement database) to the low-quality image (such as surveillance camera image) may cause the failure of the identification process. This fact means that it is necessary to research the image quality features in order to unify images and increase the accuracy rate in identification process.

Experimental research, described in this work, was performed in three stages with an aim to determine the dependency of the identification accuracy rate on properties of the database images and testing images sample, such as: image format, image resolution, face region that covers the image.

Keywords[1]

Information technology, biometric identification, face recognition

1. Introduction

Face recognition is a widely used technology that has been developed in usage from the function of smartphone unlocking or tagging people in social networks to the law enforcement technology of person identification to prevent crime and finding missing children. Many countries have made tremendous progress in applying this technology in various fields. Face recognition information is currently being used by law enforcement to make policing decisions, and might in the future be employed by public or private bodies to make decisions as to e.g. your suitability for a job, a university course or loans, overseas travel, or entry into a festival.

According to the Comparitech report [1], cities in China are under the heaviest CCTV surveillance in the world. 11 out of the top 20 most surveilled cities (based on the number of cameras per square mile) are based in China. Delhi is in the list of most surveilled cities in the world among other major international hubs like US' New York city, China's Shanghai and UK's London. The Indian government stated it is needed to improve security measures in a severely under-policed country [2]. According to IHS Markit report by the end of 2021 there were expected over 1 billion surveillance cameras will be installed worldwide [3]. Also, Comparitech researchers compared the number of public surveillance cameras with the crime indices reported by Numbeo [4] and found out the little correlation between the higher number of cameras and lower crime index. Due to the rapid spread of video surveillance systems

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appliance, with the possible further use of the data obtained in this way by law enforcement, face recognition algorithms must be highly accurate in order to allow further identification of the person and avoid false or false positive identification results.

Nowadays, face recognition and identification technologies are widely used by Ukrainian government and independent organizations during the Russian-Ukrainian War with the purpose of identifying Russian soldiers and to verify that travelers in Ukraine are who they claim [5]. Particularly, some investigators in Ukraine are using Clearview AI software, the tool able to identify a suspect caught on surveillance video, to build war crimes cases [6]. However, this method has also become a subject of criticism, because any mistakes made by the software or those using it could have dire consequences in a war zone [7]. Therefore, it is still necessary to investigate the possibilities to increase the efficiency of face recognition and identification algorithms on the images of low quality obtained from video stream or in conditions of inability to distinguish face features by widely used methods.

In previous work [8] it was found out that the accuracy rate of the algorithm applied for face recognition and identification can significantly vary on different datasets. It is common that law enforcement databases contain images of high quality such as passport image or mugshot image. On the other hand, surveillance cameras often provide images of lower quality. Such variety may create the situation when face images of a person to be identified compares with images from the database, and those images are not unified. This problem can cause the failure of the identification process and the fact of it means the necessity to research the prerequisites of that process with the purpose to increase the identification accuracy rate in video stream of surveillance cameras.

2. Task Definition and Solution Methods

For the problem that the face image from surveillance video stream with law quality cannot be accurately identified in comparison with high quality database images, this paper proposes a study of information technology for person identification in video stream proposed in [8]. The algorithm that underlies in previously proposed information technology provides person identification in video stream and establishes on such methods as anisotropic diffusion, Gabor wavelet transform, histogram of oriented gradients (HOG) and local binary patterns in 1-dimensional space (1DLBP).

First stage of the algorithm consists in capturing the snapshot of the person in video stream and transforming it into image. Then face detection and localization processes are performed on this image. An example of the algorithm performance on this stage is presented in Figure 1.

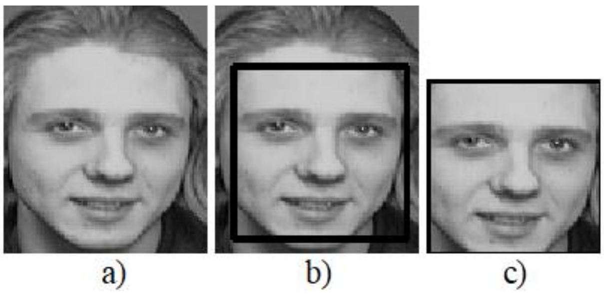

Figure 1: Example of: a) original image; b) image with detected and localized face region; c) image that contains face region only.

Face image obtained after the first stage preprocesses with anisotropic diffusion method [9]. It is used for image noise removal with image details and edges preservation. This process can be described with the following equation [10]:

$$I_t = div(c(x, y, t)\, \Delta I^2), \quad (1)$$

where *div* is the divergence operator, *c(x, y, t)* is a family of derived images obtained by convolving the original image $I_0(x, y)$ with a Gaussian kernel $G(x, y, t_0)$, Δ is the Laplacian operator.

After applying of anisotropic diffusion on face image, it processes by Gabor wavelet transform with various parameters changes in the wavelet function allowing to obtain 16 transformed variations of the input face image. An example of image processing with Gabor wavelet transform is presented in Figure

2. The result of this stage is a global image obtained by summing of those images into one global image. Gabor wavelet transform in spatial domain is based on the following formula [11]:

$$(x, y) = s(x, y)w_r(x, y), \quad (2)$$

Complex sinewave *s*, which is the carrier, defines as:

$$(x, y) = exp(j(2\pi(u_0x + v_0y) + P)), \quad (3)$$

where *(u_0, y_0)* is the spatial frequency and *P* is the sinewave phase.

Gaussian 2-dimensional function w_r, which is the envelope function, can be represented with the following:

$$w_r(x, y) = K \cdot exp(-\pi(a^2(x - x_0)_r^2 + b^2(y - y_0)_r^2)), \quad (4)$$

where *(x_0, y_0)* is the function peak, *a* and *b* are the scaling parameters of Gaussian, *r* defines the rotation operation:

$$(x - x_0)_r = (x - x_0) \cos\theta + (y - y_0) \sin\theta, \quad (5)$$

$$(y - y_0)_r = -(x - x_0) \sin\theta + (y - y_0), \quad (6)$$

After all previously mentioned notations, complex Gabor function in the spatial domain can be written as follows [9]:

$$g(x, y) = K \cdot \exp\left(-\pi(a^2(x - x_0)_r^2 + b^2(y - y_0)_r^2)\right) \cdot \cdot exp(j(2\pi(u_0x + v_0y) + P), \quad (7)$$

Figure 2: Example of image processing with Gabor wavelet transform

On the next stage global image obtained after Gabor wavelet transform processes to form two feature vectors by histogram of oriented gradients (HOG) and local binary patterns in 1-dimensional space (1DLBP). Using the method of histogram of oriented gradients allows to obtain gradient values for each cell of the matrix, that represents the image, normalize and group those values into the 512-valued feature vector [12]. During this process, magnitude and direction of the gradient can be calculated respectively as follows:

$$|G| = \sqrt{I_x^2 + I_y^2}, \quad (8)$$

$$\theta = arctan\,\frac{I_x}{I_y}. \quad (9)$$

Figure 3 demonstrated an example of histogram of oriented gradients deriving from the image.

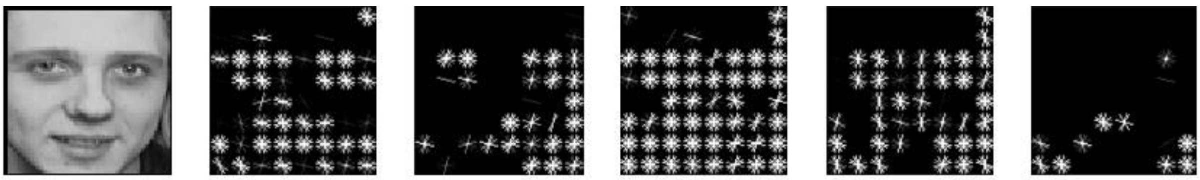

Figure 3: Example of histogram of oriented gradients deriving from the images processed with Gabor wavelet transform

Method of extracting local binary patterns in 1-dimensional space transforms local fluctuations of image segment in binary code by comparing neighbor pixel values with central pixel of the segment. Pixels, that are grater or equal to the central pixel value, possesses value of 1, and value of 0 otherwise. After that transformed segment get replaced by the sum of obtained values [13]. Thus, 1DLBP descriptor can be obtained:

$$1DLBP = \sum_{n=0}^{N-1} R(p_n - p_0) \cdot 2^n, \quad (10)$$

where *R(x)* is function of pixel value defining; p_n and p_0 are the values of current pixel and central pixel, respectively. Result of 1DLBP method is the 512-valued feature vector.

After HOG and 1DLBP feature vectors have been received, it is necessary to normalize them with the purpose of the following concatenation. Normalization performs by min-max method that transforms the feature vector values in the range from 0 to 1. Normalized vectors get concatenated to form the global feature vector of 1024 values. Global feature vector can be used in further classification process. Three face databases were used to perform the research of the proposed technology: The Database of Faces, Facial Recognition Technology (FERET) database and Surveillance Cameras Face Database (SCface). Analysis of the experimentational results indicated that the proposed information technology allows to obtain high identification accuracy rate on low-resolution face images. The highest identification accuracy rate of 92.5% was obtained on the images from SCface database, and identification accuracy rates from 70 to 72.5% were obtained on the Database of Faces and FERET database. As a consequence of such variation of the obtained results, the following problem arose: if the algorithm provides the high identification accuracy rate on the set of certain images, what affecting factors reduce its efficiency on the sets of images from other databases. With this problem in mind, it was decided to conduct the experimental research to determine the dependency of the identification accuracy rate on the following image properties: image format, image resolution, face region that covers the image. Additionally, it was resolved to examine the algorithm results on the images that contain the occlusion and on the images that were preprocessed supplementary methods.

3. Experimental Research

Experimental research was performed in three stages with an aim to determine the dependency of the identification accuracy rate on properties of the database images and testing images sample, such as: image format, image resolution, face region that covers the image.

For the experiments three face image databases were used: prepared by AT&T Laboratories Cambridge the Database of Faces (DoF) [14] – contains 40 directories with 10 PGM 92x112-sized images with 256 grey levels per pixel in each directory, distributed by The National Institute of Standards and Technology (NIST) Facial Recognition Technology database (FERET) [15] – contains 14126 high-resolution images of 1199 individuals with the resolution of 256x384, and Surveillance Cameras Face Database (SCface) [16], described in detail in [17] – contains 4160 static images of 130 individuals. Since the Database of Faces contains images of total 40 people, it was decided to use images of 40 people as well to conduct the experiments on FERET and SCface databases [8], so that the obtained results could be more clearly compared.

3.1. Experiments with Format

First set of experiments was performed with the conversion of original images from the previously mentioned databases to the BMP, PNG (compressed) and JPG (uncompressed) image formats. Results of these experiments are presented in the Table 1. As can be concluded from the comparative diagram in Figure 4, the format conversion did not affect the experimentational results for the SCface database - identification accuracy rate inalterably equals to 92.5%. Considering the experimentational results for images from the Database of Faces, can be seen that the conversion of the original image format, which is PGM, to the JPG improved the obtained result from 70 to 75%. On the contrary, result for the FERET database decreased on 2.5% with the image conversion to JPG format, while being stably equal to 72.5% with the image conversion to the BMP and PNG formats.

3.2. Experiments with Resolution

With the aim to determine the dependency of the identification rate on the image resolution, it was decided to perform the experiments with the various resolution values.

As far as all databases used in this work contain images with different initial resolution, and to convert these images to the single resolution it is required either increase or decrease their height and width values, it is impossible to select only one conversion method. Therefore, it was decided to perform the experiment that compare these two methods and converts the images to the resolution, that is acceptable for the images from all databases, regardless of whether image resolution needed to be increased or decreased. The image format was selected on the basis of previously obtained results. So, the setup for this experiment is the following: images resolution is width x 100, images format – JPG. The experimental results are divergent for both methods. On different databases one of the methods can exceed the identification accuracy rate of the other method as well as inferior it. Due to this result, for the performance of the experiment on the image resolution it was decided to use both of these methods considering if increasing or decreasing of the image resolution is needed.

Table 1

Results of experiments performed with format conversion of the images

	Original image		BMP		PNG		JPG	
	Accuracy	Error	Accuracy	Error	Accuracy	Error	Accuracy	Error
				The Database of Faces				
Total images / individuals	120 / 40		120 / 40		120 / 40		120 / 40	
Number of images	28	12	26	14	28	12	26	14
Identification rate	70%	30%	65%	35%	70%	30%	65%	35%
				FERET				
Total images / individuals	99 / 40		99 / 40		99 / 40		99 / 40	
Number of images	29	11	29	11	29	11	28	12
Identification rate	72.5%	27.5%	72.5%	27.5%	72.5%	27.5%	70%	30%
				SCface				
Total images / individuals	160 / 40		160 / 40		160 / 40		160 / 40	
Number of images	37	3	37	3	37	3	37	3
Identification rate	92.5%	7.5%	92.5%	7.5%	92.5%	7.5%	92.5%	7.5%

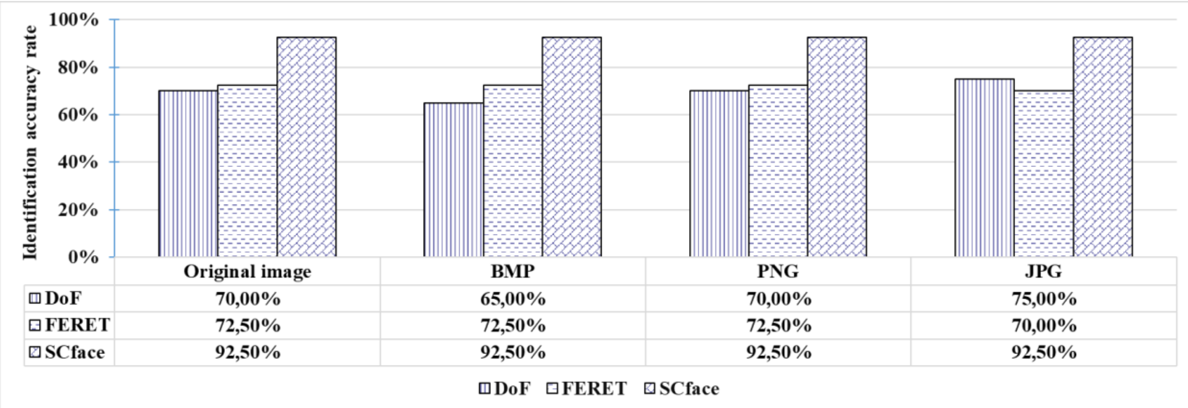

Figure 4: Comparative diagram of the results obtained on the experiments performed with the image format conversion

As following from the analysis of previous experimental research, the highest identification accuracy rate was obtained as the result of algorithm appliance on the images from SCface database, that contains image with the resolution of 75x100, 96x128 and 108x144 pixels. The same resolution values were chosen to perform the experiments with the resolution conversion on the other databases, as well as for the SCface database with all images conversion to the unitary resolution.

For image resolution conversion the thumbnail function was used on early stages of the research. During the experiments it was found that the images from the Databases of Faces cannot be converted to the size of 75x100 with thumbnail function only, instead images were converted to the resolution of 75x91 pixels. Since the obtained results on this resolution seemed promising, it was decided to use this resolution for the experiments as well.

In preparation of the experiments, it was important to convert images to the same resolution values. But, as far as all used databases contain initial images with different resolution, the aspect ratio of the images could have been changed. Consequently, the image features could have been changed as well, including the features of the face depicted on the images, which is essential in face recognition tasks. So, the image resolution was converted by the single height keeping the aspect ratio unchanged with automatically defined value of the image width. As the result, experiments were performed with the following resolution values: 75x91, 75x100, 96x128 and 108x144 – for the Database of Faces; 61x91, 67x100, 85x128 and 96x144 – for the FERET database; 68x91, 75x100, 96x128 and 108x144 – for the SCface database. Also, the format of the images was changed accordingly to the first set of the experiments. The results of experiments are presented in the Table 2.

Table 2

Results of experiments performed with resolution conversion of the images

	width x 91		width x 100		width x 128		width x 144	
	Accuracy	Error	Accuracy	Error	Accuracy	Error	Accuracy	Error
The Database of Faces								
Total images / individuals	120 / 40		120 / 40		120 / 40		120 / 40	
BMP								
Number of images	31	9	26	14	27	13	28	12
Identification rate	77.5%	22.5%	65%	35%	67.5%	32.5%	70%	30%
PNG								
Number of images	31	9	26	14	28	12	28	12
Identification rate	77.5%	22.5%	65%	35%	70%	30%	70%	30%
JPG								
Number of images	30	10	24	16	22	18	29	11
Identification rate	75%	25%	60%	40%	55%	45%	72.5%	27.5%
FERET								
Total images / individuals	99 / 40		99 / 40		99 / 40		99 / 40	
BMP, PNG								
Number of images	21	19	24	16	29	11	29	11
Identification rate	52.5%	47.5%	60%	40%	72.5%	27.5%	72.5%	27.5%
JPG								
Number of images	22	18	25	15	27	13	30	10
Identification rate	55%	45%	62.5%	37.5%	67.5%	32.5%	75%	25%
SCface								
Total images / individuals	160 / 40		160 / 40		160 / 40		160 / 40	
BMP, PNG								
Number of images	25	15	27	13	33	7	37	3
Identification rate	62.5%	37.5%	67.5%	32.5%	82.5%	17.5%	92.5%	7.5%
JPG								
Number of images	25	15	31	9	35	5	38	2
Identification rate	62.5%	37.5%	77.5%	22.5%	87.5%	12.5%	95%	5%

Figures 5-7 depict results obtained after experiments on the image resolution, the following conclusions can be drawn. The appliance of the resolution conversion methods on the images from the Database of Faces increased the identification accuracy rate from 70% on initial images to 77.5% on images with resolution 75x91 pixels converted to BMP and PNG images. In relation to the results of single format conversion obtained results increased on 2.5%. Results on converted resolution of 82x100, 105x128 and 118x144 in compare to previously obtained results decreased to 55-72.5%.

Identification accuracy rates obtained on the FERET database significantly decreased after image resolution conversion to 61x91 and 67x100 pixels – from 72.5% to 52.5-62.5%. On the other hand, the results are steadily equal to the previously obtained result of 72.5% on BMP and PNG images with the resolution of 85x128 and 96x144 pixels. And the result for 96x144 pixeled JPG images is the highest among all obtained on the FERET database, equals to 75%.

Results for the SCface database images decreased after being converted to the resolution of 68x91, 75x100 and 96x128 pixels. Identification accuracy rate varies from 62.5% to 87.5%. On contrary, image resolution conversion to 108x144 pixels allowed to obtain the result of the initial 92.5% on BMP and PNG images and the highest result of 95% on JPG images.

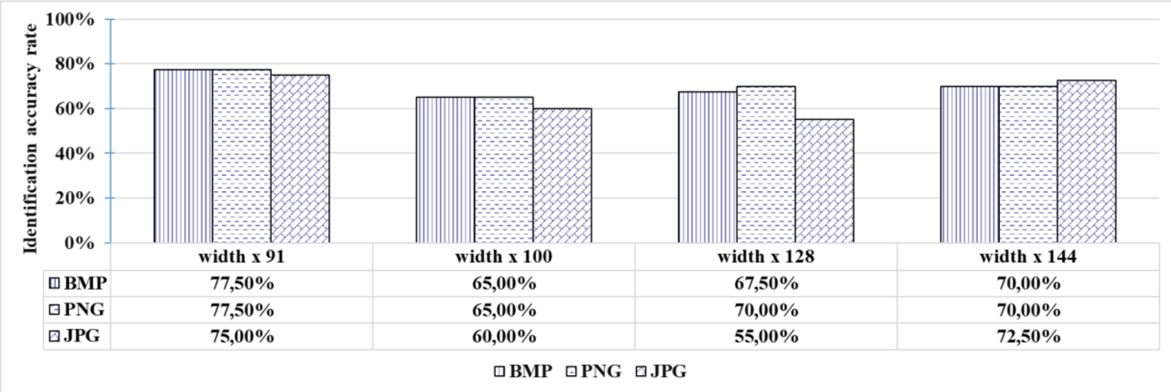

Figure 5: Resolution conversion experimental results for images from the Database of Faces

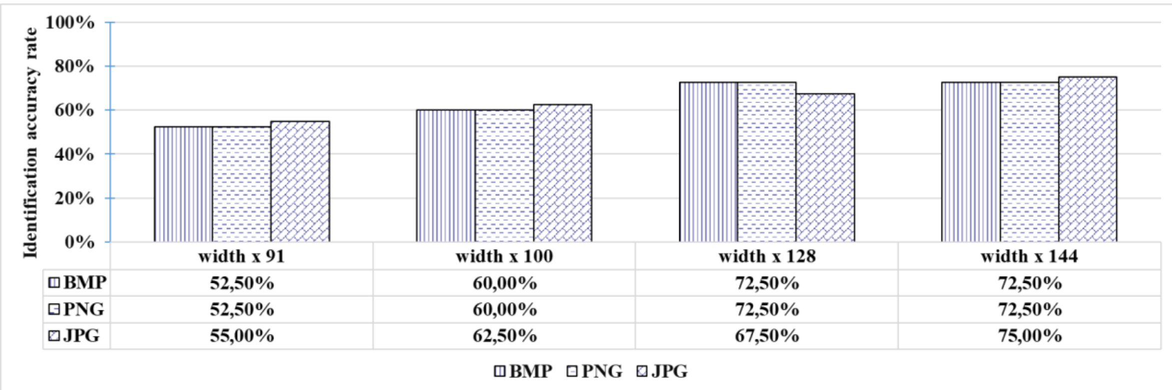

Figure 6: Resolution conversion experimental results for images from the FERET database

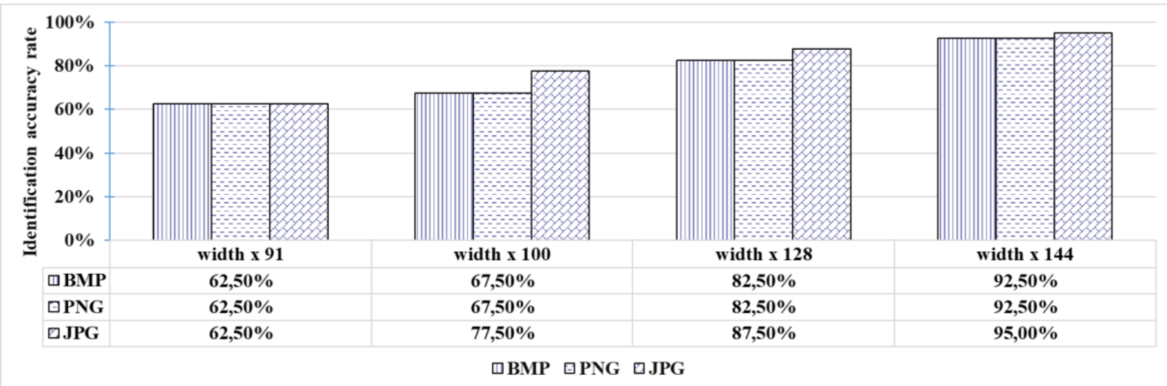

Figure 7: Resolution conversion experimental results for images from the SCface database

3.3. Experiments with Face Region Image Resolution

On the next stage of the experimental research, it was decided to define if the identification accuracy rate depends on the size of the face region that images contain. For this purpose, the experiment that provided the highest identification accuracy rate result during the previous research, in particular, the experiment on the JPG images that SCface database contains, was analyzed. As a result of analysis, it was determined that the images with the face region of 47x47 and 78x78 pixels were correctly identified in the majority of experiments. Size of the face region on the images from the SCface database varies due to the fact that initial etalon and testing images have different sizes as well. Hence, it was decided to use mentioned sizes for the purpose of the experimental research in this work. Also, to determine the variety of the identification rate beyond the selected sizes, it was decided to conduct the experiments on the images that contain face region below and beyond the threshold values (32x32 and 128x128), and between the selected values and threshold values (64x64). Thereby, the experiments on the face image region were performed as: face detection on the image, conversion of the obtained face region to the selected size, input of the image containing only face region of the size of 32x32, 47x47, 64x64, 78x78 or 128x128 pixels to the algorithm. Table 3 contains the results of the described experiments.

Table 3

Results of experiments performed with resolution conversion of the face region images

	32x32		47x47		64x64		78x78		128x128	
	Accuracy	Error	Accuracy	Error	Accuracy	Error	Accuracy	Error	Accuracy	Error
The Database of Faces										
Total images / individuals	120 / 40		120 / 40		120 / 40		120 / 40		120 / 40	
BMP, PNG										
Number of images	1	39	1	39	18	22	18	22	10	30
Identification rate	2.5%	97.5%	2.5%	97.5%	45%	55%	45%	55%	25%	75%
JPG										
Number of images	1	39	1	39	21	19	17	23	11	29
Identification rate	2.5%	97.5%	2.5%	97.5%	52.5%	47.5%	42.5%	57.5%	27.5%	72.5%
FERET										
Total images / individuals	99 / 40		99 / 40		99 / 40		99 / 40		99 / 40	
BMP, PNG										
Number of images	1	39	13	27	27	13	28	12	28	12
Identification rate	2.5%	97.5%	32.5%	67.5%	67.5%	32.5%	70%	30%	70%	30%
JPG										
Number of images	1	39	13	27	27	13	28	12	26	14
Identification rate	2.5%	97.5%	32.5%	67.5%	67.5%	32.5%	70%	30%	65%	35%
SCface										
Total images / individuals	160 / 40		160 / 40		160 / 40		160 / 40		160 / 40	
BMP, PNG										
Number of images	1	39	26	14	34	6	33	7	34	6
Identification rate	2.5%	97.5%	65%	35%	85%	15%	82.5%	17.5%	85%	15%
JPG										
Number of images	1	39	27	13	37	3	36	4	32	8
Identification rate	2.5%	97.5%	67.5%	32.5%	92.5%	7.5%	90%	10%	80%	20%

Consequently, as can be seen on the Figures 8-10, the identification accuracy rate does not depend on whether the etalon images and testing images samples contain any other detail than the face region itself. The algorithm contains methods for face detection and image resizing, that solve the task independently, regardless of the quality of the input data. Considering the variety of results on the same resolutions of the face region images, it still necessary to research methods of face region image conversion in order to unify it.

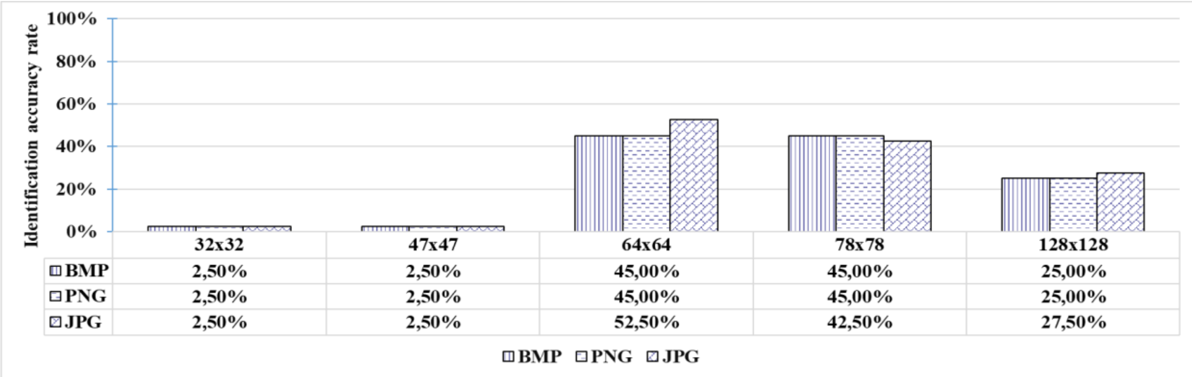

Figure 8: Face region detection experimental results on the images from the Database of Faces

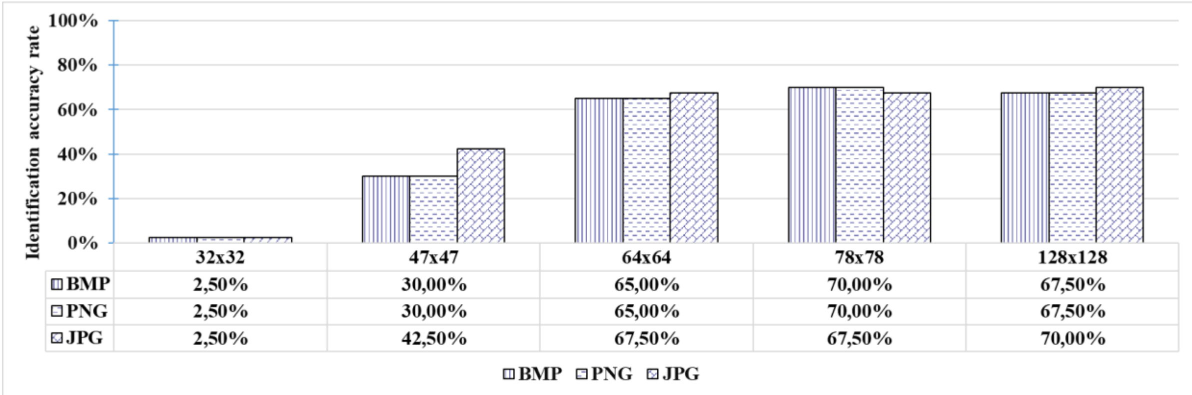

Figure 9: Face region detection experimental results on the images from the FERET database

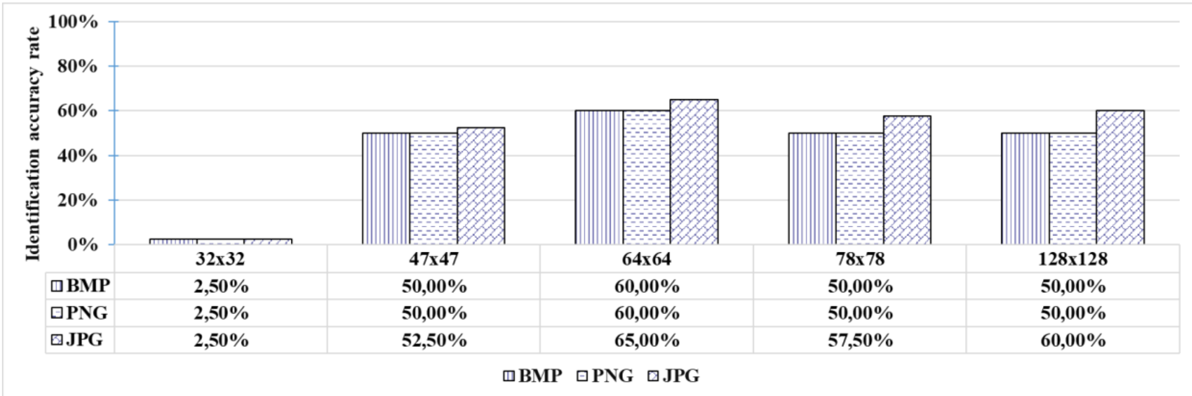

Figure 10: Face region detection experimental results on the images from the SCface database

Also, during the research it was found out that identification accuracy rate does not depend on whether the etalon images and testing images samples contain any other detail than the face region.

For further research of investigated algorithm that is underlies in face recognition and identification technology it is needed to continue the experiments with a change of parameters in methods of unifying image formats and resolutions, as well as reconsider selection of preprocessing methods and image classification methods.

4. Conclusion

This paper is devoted to the research of information technology for person identification in order to enhance its efficiency by studying features of the comparing images. The image features that were studied are the format, resolution and face region covering the image.

The format conversion to the JPG improved the obtained result for the Database of faces from 70 to 75% and did not affect the results on the images from other databases.

The appliance of the resolution conversion methods on the images from the Database of Faces increased the identification accuracy rate from 70% on initial images to 77.5% on images with resolution 75x91 pixels converted to BMP and PNG images. The result for 96x144 pixeled JPG images is the highest among all obtained on the FERET database and equals to 75%. Image resolution conversion to 108x144 pixels allowed to obtain the result of the initial 92.5% on BMP and PNG images and the highest result of 95% on JPG images.

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