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ALGORITHMS FOR THE PREPROCESSING OF FACIAL IMAGES ON BIOMETRIC SYSTEMS

[1]***Radjabov S.S.***, [1]***Abdullaev Sh.Sh.***, [1]***Urinov E.M.***, [2]***Dadakhanov M.X.***
s_radjabov@yahoo.com; shash_8707@mail.ru; eltn1101@gmail.com; mxd75@mail.ru
[1]Scientific and innovation center of information and communication technologies;
[2]Namangan State University

One of the promising and rapidly developing areas of modern information technologies is associated with the tasks of identifying an individual according to the biometric characteristics (features) of a person. Among them, the identification of the person on the image of the person is recognized as the most acceptable for mass use. The advantages of personal identification systems in face image are unobtrusive (identification is carried out at a distance without delaying or distracting a person), passivity (does not require special knowledge or actions from the user) and relatively low cost (having a computer, video camera and appropriate software is enough). However, the issues of development and application of algorithms for pre-processing images of a person when identifying a person are little studied. The goal of this work is to comparatively analyze the main algorithms for the preprocessing of a face image and to choose the most effective of them. To achieve this goal, an analytical review of the algorithms of geometric normalization of the face image, alignment of its illumination, and also the elimination of noise has been carried out. When developing personal identification systems based on facial image analysis, the considered algorithms are used at the stage of preliminary processing of initial images. This stage is important, as its results significantly affect the final result of the system.

Keywords: image brightness and contrast, noise elimination, image histogram, geometric normalization, alignment of illumination

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1 Introduction

While identifying a person based on the facial image analysis, image quality has a great impact on the system performance accuracy. Therefore, it is important to organize the process of capturing the image and video using the camera and camcorder as well as accomplishing the initial processing the images correctly. Each year, millions of surveillance cameras are being installed. When viewing video recordings to find details of an event, the quality of the images is not sufficient to identify people or car numbers. This means that a large number of resources and tools are being wasted. If the project requires the identification of people or numbers in the surveillance system, it is important to take into account the factors such as the degree of illumination, location and movement of the camera.

The main goal of improving the quality of images is to achieve the most appropriate results in a particular direction. For example, a person's identification based on a facial image analysis. The result of image processing is also considered as an image. Methods for improving image quality are divided into two major groups [1]:

– spatial methods;

– frequency methods.

Space methods are based on the processing of images as they are regarded as pixels on the plane. Frequency methods are based on the alteration of images generated by Fure substitution (Ideal for high and low frequency filter, Battervort filter, a Gaussian filter). There is no general theory of image quality improvements [1].

When developing a personal identification system based on image analysis may arise various problems. The most important of these are the location of the camera and the distance from the object to the optimality, the number of pixels in the image associated with the digitization parameters, uneven distribution of lighting, contrast, intensity (color saturation) of the original image. In addition, the interruptions in the capture and image digitization stage can be accompanied by anxiety (face expression - neutral, anxious, cheerful, etc.), facial obstruction (hair loss, hair, beard, eyeglasses) other factors, such as wrinkles, wrinkles, wrinkles, etc..The following are some of the methods and algorithms that can be used to resolve the most common problems of these problems.

2 Geometrical image normalization algorithms

Persons identified at any time on images cannot be in the correct position and size, as required by the recognition system. Before comparing the two faces, it is necessary to get them to be standardized first. To normalize the face image, you need to adjust this image and zoom in the same size. To accomplish these actions, the coordinates of the center of the eye center of vision are determined using the Viola-Djons algorithm [2–6]. Let's look at the steps outlined above.

2.1 Face image correction

In order to do this, a line is used through the center of the left and right eye pupils. The deviation of the centers of the left and right eye are considered. The angle between the horizontal line and the eye line is determined. If the angular value is less than 6, the normalization is done by turning to the angle (Figure 1). Otherwise the image will be considered as normalized.

The angle of rotation is determined by the following formula:

$$\alpha = -arctan\,(b_y/b_x)$$

where b is a vector of polar centers.

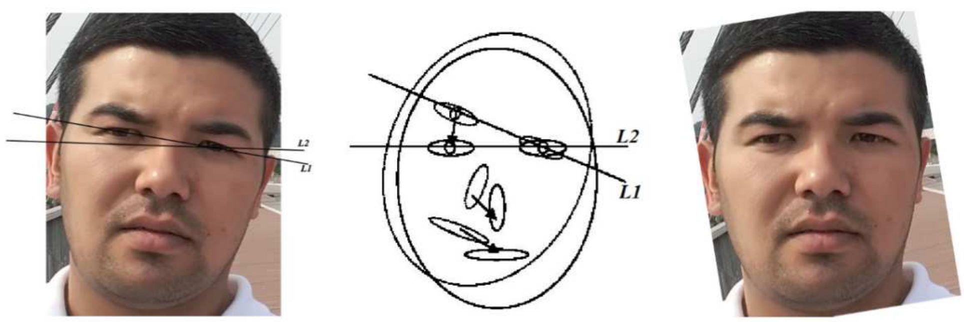

Figure 1 Geometric normalization of facial image

The rotation matrix is expressed in the following way:

$$T = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix},$$

where α is the angle of rotation. The new point of the point (x, y) is calculated as follows:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = T^* \begin{pmatrix} x \\ y \end{pmatrix}.$$

Changing the rotation algorithm as follows allows minimizing image corruption. The rotation matrix is expressed in multiplication of three matrices:

$$\begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} = \begin{pmatrix} 1 & a \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 \\ b & 1 \end{pmatrix} \begin{pmatrix} 1 & c \\ 0 & 1 \end{pmatrix}$$

here, $a = tg\alpha/2$; $b = -\sin\alpha$; $c = tg\alpha/2$.
The first matrix is applied to move the image pixels to the horizontal pixels, and the second matrix to move the column pixels to vertical axis and third matrix is to make horizontal slope. The resulting image does not generate scratches because the resulting image is the result of moving the pixels of the original image to a specific location.

2.2 Scale normalization

Before comparing the two face images, it is necessary to bring them to a standard vision. The left and right eyes should be in a horizontal line and the distance between their pupils must always have a fixed value. In the process of normalizing the zoom, the number of pixels between the eyeball should be set to a specific value based on the algorithm, software or system requirements. The proportion of coefficients is defined as follows:

$$k = (eye\_dist)/|b|,$$

where eye_dist is the fixed distance between the centers of the eye pupil. The zoom algorithm can be built on the nearest neighbor principle. The brightness of a new frame (x', y') is determined by the following formula:

$$f(x', y') = g([x'/k], [y'/k]).$$

Here is the closest integer to $[x] - x; g(x, y)$ is the brightness of the original image; k - scale coefficient, $k > 0$.

3 Algorithms alignment of illumination on images

While doing a person's identification and working with images one has to work with non-contrasting images that do not have a high brightness range. These drawbacks in the graphics significantly reduce system authenticity. There are many algorithms to improve the visual appearance of such images. The most appropriate algorithm and its parameters are selected depending on the image being processed. The most commonly used algorithms for the brightness level are Auto Levels, Gamma Correction, Single-Scale Retinex, Multi-Scale Retinex algorithm and its modifications [8–10].

3.1 Auto Levels

The "Auto Levels"algorithm promotes image contrast enhancement through the intensification of all channels. This algorithm is based on the principle that "the darkest color in the image is black and the brightest color is white" [1].

Image enhancement is based on the following formula:

$$I_{new} = 255 * (I - I_{min})/(I_{max} - I_{min}).$$

Here's the new value of the I_{new} pixels spectrum, Current, maximum and minimum values of the pixel spectrum in I, I_{max} and I_{min}

3.2 Gamma correction

The gamma correction algorithm is based on the change in the intensity of image pixels. The first purpose of the algorithm is to correct the image for correct viewing on the monitor. Intensity correction is done by the following formula [1]:

$$I_{new} = c * I^{\gamma}.$$

It should be noted that these algorithms do not take into account surrounding pixels, so these algorithms do not provide a good quality picture when there are strong dark and strong light local areas. In such cases it is desirable to use the Retinex algorithm [12] and its modifications.

3.3 Retinex algorithms family

The family of these algorithms is based on the Single-Scale Retinex (SSR) [11] algorithm and serves to alter the color image illumination. These include the MultiScale Retinex algorithm and its modifications.

The Multi-Scale Retinex (MSR) [12] algorithm compresses the dynamic range by maintaining local contrast in low-brightness and strongly lit areas of the image. The classic multi-dimensional MSR-algorithm is a weighted sum of one-dimensional SSR (Single-Scale Retinex) algorithm [7, 8] for different dimensions. One-dimensional output function of the i-channel is $R_i(x, y, \sigma)$ [10].

$$R_i\left(x, y, \sigma\right) = log\frac{I_i\left(x, y\right)}{G\left(x, y, \sigma\right) * I_i\left(x, y\right)}.$$

Here is the function of the $I_i(x, y)$ i-color channel's x and y coordinates; s-scale coefficient; $*$ The symbol represents the function slider; $G(x, y, s)$ - Gaussian. The final output function for the i-color channel (x, y, ω, σ) is defined as follows [10]:

$$RM_i\left(x, y, \omega, \sigma\right) = \sum_{n=1}^{N} \omega_n R_i\left(x, y,\ \sigma_n\right).$$

Further improvements have been made to algorithms MSRCP (chromaticity preservation) and MSRCR (Color Restoration), which are modifications to the proposed algorithm.

MSR algorithm modifications MSRCR (Color Restoration) and MSRCP (chromaticity preservation) MSRCR (Color Restoration). This algorithm completes the color-back function. Nevertheless, this algorithm reduces the intensity of colors in processing images that are dominant in any color. One of the best solutions to this problem is using the MSR algorithm in the intensity channel. The original color of the image is preserved. The intensity of the channels is determined by the formula $I = \frac{\sum_{j=1}^{S} I_j}{S}$. Here is the S channel number sequence number. In this version of MSR R_I is defined by the following formula [13, 14]:

$$R_{MSR_i} = \sum_{n=1}^{N} \omega_n R_{n_i} = \sum_{n=1}^{N} \omega_n [\log I_i (x,y) - log\,(F_n (x,y) * I_i (x,y))].$$

The final results for each color channel can be calculated as follows:

$$R_i = I_i \frac{R_I}{I}$$

MSRCP (chromaticity preservation) algorithm, the color balance is well preserved and the resulting image is the same as the original image. This algorithm is best used with white lightning and color distributed images. The MSRCP algorithm retains the original color when the results of the MSRCR reduce the intensity of the color [14].
The following Figure 2 shows the results of the algorithm of brightness alignments, and the use of the MSR algorithm in the intensity channel can be a good result.

Figure 2 The results of brightness algorithms: a) the original image; b) Auto Levels; c) Multi-Scale Retinex; d) MSR on intensity channel

For most images, the following values are best defined by experiments that give the best results, as shown in Table 1 [11, 12].

Table 1 Multi-Scale Retinex algorithm constants

Constant	N	σ_1	σ_2	σ_3	α	β	ω	G	b
value	3	15	80	250	125	46	1/3	192	-30

3.4 Contrast enhancement

Contrast is the unity dimension measured by the ratio of the brightness values. There are various ways to calculate it [16]:

$$K = \frac{B_1 - B_2}{B_1}.$$

Here B_1 is the brightness of a object (face) and B_2 background brightness.
Michelson method of calculation

$$\gamma = \frac{B_{max} - B_{min}}{B_{max} + B_{min}}.$$

Here are the brightest and darkest bright spots in B_{max} and B_{min}. There is also a mid-square contrast value

$$K = \sqrt{\frac{1}{MN} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \left(B_{ij} - \bar{B}\right)^2}.$$

Contrast of images can be enhanced by using the histogram algorithm. In this algorithm the brightness histogram of the picture stretches and stretches across the range, resulting in contrast increase. Programming this algorithm is one of the easiest ways [1, 15].

Contrast Limited Adaptive Histogram Equalization-CLAHE. Although this algorithm is effective in processing the range of brightness in a completely incompatible medicine, it can not be used for photographic or video images as the result of an artifact. The following illustration (Figure 3) shows the gray image based on the CLAHE algorithm.

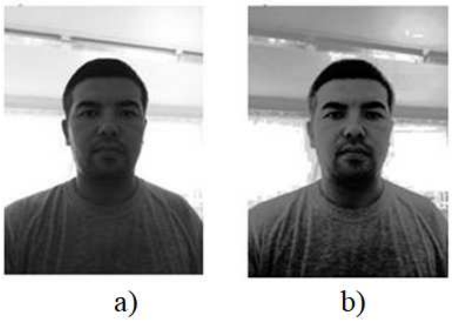

Figure 3 The result of the CLAHE algorithm: a) original image; b) result of algorithm

4 Algorithms for removing noises that appear during the rendering and image digitization phase

Under low illumination, the camera's light-sensitive matrices create significant noises, resulting in poor image quality. This complicates the issue of identity. Eliminating noises. Noise is the image created by the electronics and photographer of the device (digital cameras, tele-camcorders, etc.) as a result of photon nature of the light and incomplete technologies. Hypersensitivity include impulse noises, Gaussian-type noises.

Median filter. Impulsive (salt and pepper) is very effective in the removal of noises. The mediana filter replaces the value of each pixel with the median value based on the analysis of its surrounding neighbors. The median value is the value of the element that is between that array. The Mediana filter is not effective in Gaussian-type noises.

Anisotropic diffusion is a method of reducing noise from image without removing significant parts of the image [17]. This method was first proposed by D. Gabon in 1965 and later by Peron and Malik in 1990. The method is part of the nonlinear and space methods. The main idea of the method is the inverse proportion of the gradient value in each direction to the gradient value in that direction. Anisotropic diffusion is an iterative process. The purpose of the full regulation of noise diversities (total variation regularization) algorithm is to eliminate interference when there are many noises in the image and maintain the state of the image as original as possible. Here the noises are removed keeping good boundaries of important details in the picture. This algorithm has a widely used application for processing signals and digital images. This technology of noise removal is more effective than linear straightening and median filtering and even interferes with low signal-cost advantage. It was first proposed by Rudin, Asher and Fetami in 1992 [18].

Algorithm description: the output image y in this is determined as integral to the absolute gradient of the signal:

$$V\left(y\right) = \sum_{n_1} \sum_{n_2} \sqrt{\left|y\left(n_1+1,\ n_2\right) - y\left(n_1, n_2\right)\right|^2 + \ \left|y\left(n_1,\ n_2+1\right) - y\left(n_1, n_2\right)\right|^2} \, .$$

Furthermore, the difference between incoming and outgoing images L_2 is considered by E:

$$E(x,y) = \sum_{n_1,n_2} \left(x(n_1,n_2) - y(n_1,n_2)\right)^2$$

The final function of the algorithm:

$$\hat{y} = \arg{}_{y}^{min} \left[E(x,y) + \ \lambda V(y)\right]$$

where λ is a regularization parameter.

Non-local means. Localization methods are aimed at removing noises and restoring the basic geometric configuration, but does not retain fine texture, details and texture in the image. The high-frequency components of the image will be lost along with the noises, as they will block all functional aspects.

The non-local means algorithm tries to use the over-privilege of any natural image [19]. Because the small window in the natural image has some similarity in the picture. Filtering takes into account the similarity of pixels around the pixel. This is better than the Gaussian filter, that is, the result is close to the original image. a small window in the natural image will have several similarities in that image. Filtering takes into account the similarity of pixels around the pixel. The weakness of this algorithm has also been identified, and the "method noise"that is similar to the "white noise"appears in the process of noises. Over the past few years, the above-mentioned shortcomings have been eliminated through methods such as deinterlacing [20] and lookout interpolation [21] and their software applications.

Discrete algorithm description. A certain aspect of the picture ω is considered as two points in the picture p and q. The algorithm here:

$$u(p) = \frac{1}{C(p)} \sum_{q \in \Omega} v(q) f(p,q).$$

Where $u(p)$ is the result of p point filtering, $v(q)$ the un-filtered value of the q point in the image, $f(p,q)$ is the function of gravity, and integral is calculated on $\forall_q \in \ \Omega$. $C(p)$ is the normalizing factor and it is given below:

$$C(p) = \sum_{q \in \Omega} f(p,q).$$

For the function of the Gaussian

$$f(p,q) = e^{(-|B(q)-B(p)|^2/h^2)},$$

where $B(q) = \frac{1}{|R(p)|} \sum\limits_{i \in R(p)} v(i)$ where square $R(p) \subseteq \Omega$ where p is the number of pixels in the region, $|R(p)|$. Figure 4 illustrates the algorithm of the mixed-type algorithm on the basis of non-local algorithm.

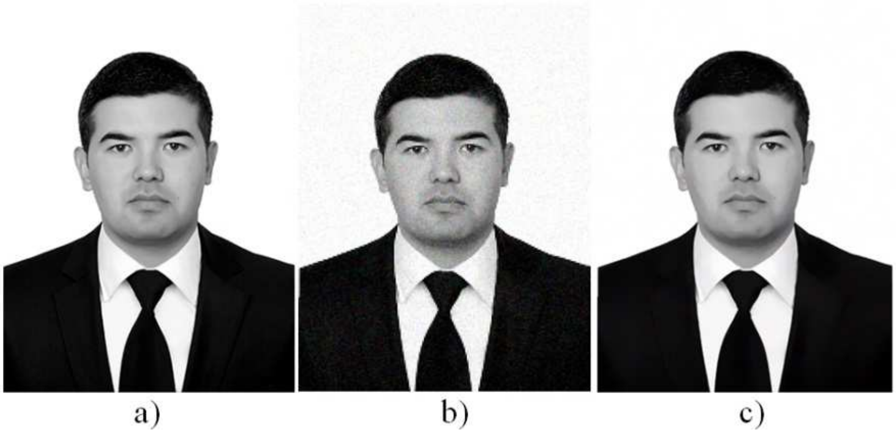

Figure 4 a) original image ; b) there is noise in the image; c) the result of the non-local means algorithm.

5 Conclusion

As a result of the research, the key issues arising in the development of personal identification systems based on the face image analysis were thoroughly studied. Methods and algorithms for solving these problems were studied and comparative analysis was performed. Shooting conditions, i.e. shooting angle, illumination status, brightness of the image are not at the required level, the intensity of the contrast, the color intensity, i.e. the appearance of color intensities, the removal of noise from image or image digitalization stage, methods and algorithms that help to recognize and identify personality through facial expressions when it comes to hair, beard, mustache, eyeglasses and headgear. as a result of admissible and comparative analysis, the most acceptable ones have been identified.

As a result of these studies, it has been established that image quality in the identification system based on the face-to-face analysis plays a crucial role in the accuracy of the system's performance.

The fast and qualitative method of geometrical normalization of the face of the person identified in the picture is given.

For inferior lighting conditions, it is recommended that the cameras should be able to capture cameras and the requirements for European standards should be selected for accurate camera distortion, recognition and identification.

The Multi-Scale Retinex algorithm and its modifications have been found to have a better result than other known algorithms when it has to work with high brightness and non-contrast images. As a result of the research, the Multi-Scale Retinex algorithm for intensiveness has been found to be useful in the initial processing of unevenly distributed facial images. The brightness, contrast, and intensity of the image are better than the result of other algorithms. Grayscale images can be used to optimize contrast and have a simpler application of software.

The algorithm of non-local means for the removal of images in the face image has been found to be more effective than other algorithms and filters, where improved algorithm variants eliminate all types of interruptions and preserve fine texture, detail and texture in the image.

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АЛГОРИТМЫ ПРЕДВАРИТЕЛЬНОЙ ОБРАБОТКИ ИЗОБРАЖЕНИЯ ЛИЦА В БИОМЕТРИЧЕСКИХ СИСТЕМАХ

[1]***Раджабов С.С.***, [1]***Абдуллаев Ш.Ш.***, [1]***Уринов Э.М.***, [2]***Дадаханов М.Х.***
s_radjabov@yahoo.com; shash_8707@mail.ru; eltn1101@gmail.com; mxd75@mail.ru
[1]Научно-инновационный центр информационно-коммуникационных технологий;
[2]Наманганский Государственный Университет

Одно из перспективных и быстро развивающихся направлений современных информационных технологий связано с задачами идентификации личности по биометрическим характеристикам (признакам) человека. Среди них идентификация личности по изображению лица признана наиболее приемлемой для массового применения. Преимуществами систем идентификации личности по изображению лица являются ненавязчивость (идентификация осуществляется на расстоянии, не задерживая и не отвлекая человека), пассивность (не требует специальных знаний или действий от пользователя) и относительно низкая стоимость (достаточно наличия компьютера, видеокамеры и соответствующего программного обеспечения). Однако вопросы разработки и применения алгоритмов предварительной обработки изображений лица при идентификации личности являются малоисследованными. Цель данной работы заключается в сравнительном анализе основных алгоритмов предварительной обработки изображения лица и выборе наиболее эффективных из них. Для достижения поставленной цели проведен аналитический обзор алгоритмов геометрической нормализации изображения лица, выравнивания ее освещенности, а также устранения шумов. При разработке систем идентификации личности на основе анализа изображения лица рассмотренные алгоритмы используются на этапе предварительной обработки исходных изображений. Данный этап является важным, так как его результаты значительно влияют на конечный результат работы системы.

Ключевые слова: яркость и контраст изображения, устранение шумов, гистограмма изображения, геометрическая нормализация, выравнивание освещенности

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