The Formation of Synthesized Image Base by Noise Influence Model

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***Abstract*—Designing the systems of automatic recognition requires using algorithms of machine learning. For learning the base of photos it must contain the objects of interest in different conditions of illumination, with different viewpoint and with different noise quantity. But indeed, it is very difficult to obtain the base of photos; also it requires not just to take pictures, but to mark areas of interest in the classes. And such a base does not allow full testing the system of recognition. These problems can be solved with the base of synthesized images.**

I. Introduction

Algorithms of machine learning, required the base of images (photos) for testing and tuning, are used at design of the car license plate automatic recognition system. The base of images has to contain objects of interest in various conditions of light, in various poses with various level of noise. When we trying to form this base, there are problems:

1) The base has to contain about several thousand images.
2) Classes labels assignment process is necessary. On each image supervisor has to allocate the plate, symbols on a the plate and write the result number.
3) Some classes of objects of interest can meet very seldom. The probability of such classes will be low.[7]

By the base of images we can define quality of recognition: there are errors of the first (false alarm) and the second sort (the false admission). Other aspect of quality control is the analysis of how well the system is trained. Situations when the algorithm is trained not enough (it tell us about simplicity of the chosen model) are undesirable or the system is overtrained (too well corresponds to the training selection and doesn't correspond to test).

Some of the described problems can be solved with the synthesized images base formation algorithm. The advantages of the synthesis algorithm are:

1) Getting practically any volume of image base in rather short time.
2) Automatic marking.
3) Obtaining images of each classes of the objects equally.
4) Obtaining metrological characteristics depending on each of the interesting parameters separately.

The purpose of this work is the analysis of the algorithm of synthesized car license plates images base.

II. The synthesized image base formation algorithm

A. Overview of algorithm

The images synthesis algorithm was carried out in system of three-dimensional modeling and rendering "Modo", with the subsequent addition of various distortions (Fig. 1).

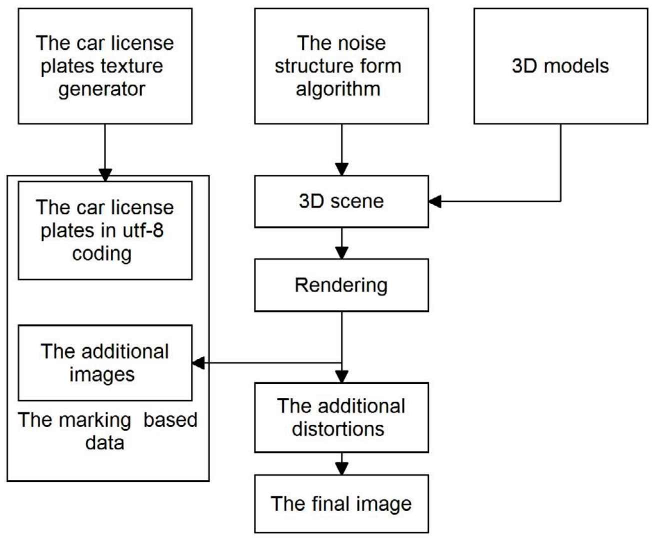


Fig. 1. Scheme of multi-focused image merging

The three-dimensional scene consists of car license plate, the car and asphalt. The texture on a license plate three-dimensional model is combination of two images: the car license plate image and structural noise. The image of the plate is generated by special program, developed taking into account the corresponding state standard specification. The image of the structural noise in this case is Perlin's noise.

Then the three-dimensional scene is visualized by the method based on an light emittance. Energy distribution from light sources to model sides, reflection, light refraction calculates by this method. At the same time in addition to the image of the three-dimensional scene the necessary for marking additional images representing an alpha mask of each objects of interest (the plate and each symbol separately) are synthesized.[3] Additional distortions in the form of the additive white Gaussian noise with dispersion 0,1 and the blocking artifacts, received by interpolation and decimation of

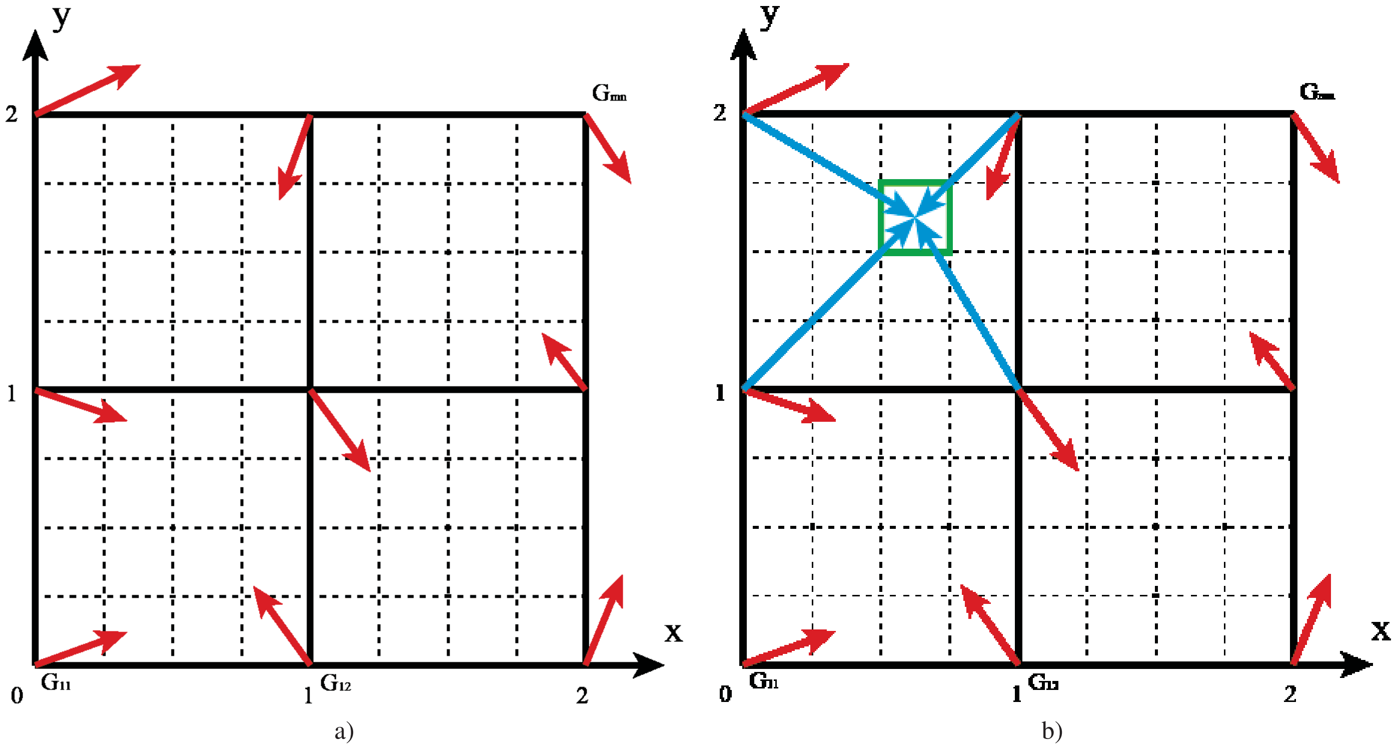


Fig. 2. Stages of Perlin's noise formation: a) Formation of a grid and normal vectors; b) Calculation of vectors from grid cell corners to the considered pixel direction

the image by 4 times, are added to the received image of a three-dimensional scene.

B. Perlin's noise

Structural noise is designate blurs on car license plates appearing during the car movement such as splashes, dust and dirt. Perlin's noise is used as imitation of structural noise because of his visual similarity.

Perlin's noise is a mathematical algorithm generating the procedural texture by a pseudorandom method. It is the gradient noise consisting of a set of pseudorandom unit vectors (the gradient directions) located in certain points of space and interpolated by smoothing function between these points. Perlin's noise was created by Ken Perlin in 1983 and subsequently called in honor of the creator. Distinctive feature of Perlin's noise from other procedural texture generation algorithms is the identical size of texture visual details. This property does Perlin's noise well-managed, thus the set of scaled Perlin's noise copies can be inserted into mathematical expressions for creation of various procedural textures. Perlin's noise is widely used in two-dimensional and three-dimensional computer graphics for creation of such visual effects as smoke, clouds, fog, fire and dust. The image (regardless of the range of values of its elements) completely is covered by the grid representing the range of real numbers (Fig. 2. a). Cell length is taken on for unit distance. The chosen scale of a grid influences on noise complexity. The bigger amount of squares on a grid of the image will create more ”densely packed” noise, which is similar to white noise. The smaller amount of squares on a grid generates the ”curling” noise, which is similar to clouds.

The random vector of a normal is formed in each point on a grid. It is a usual two-dimensional unit vector which points to the random direction within each of squares. A traditional method of creation for such vectors is the organization of the lookup table of vectors which cover a cycle and the subsequent random choice of one of them for each point on a grid. It guarantees us random distribution of vectors which can point to any direction with equal probability.[1], [2]

Each pixel receives value which is based only on data of a cell which is belonged. Then four diagonal vectors are created connecting cell corners to the considered pixel (Fig. 2. b).

Each corner of a grid cell is the base for two vectors: a random unit vector and a vector to the direction of the considered pixel. Each couple of such vectors is calculated as scalar product. Further these four values unite. It is possible to unite these values differently, receiving various results, however the weighed interpolation of four values are used taking into account proximity of the current position to each corner of a grid cell most often:

$$I(i, j) = g_a(w(x, y)) + g_b(1 - w(x, y)),$$
$$w = (6x^5 - 15x^4 + 10x^3)(6y^5 - 15y^4 + 10y^3),$$

where g_a and g_b are values of considered corners of a cell, w is weight considering proximity of pixel to a cell corner, (x, y) are pixel coordinates in relation to the considered cell corner

At first results of scalar product of vectors of top cell corners are united. Then that procedure repeats also for two values of scalar product of bottom corners. At last, results of two that uniting also are unite.

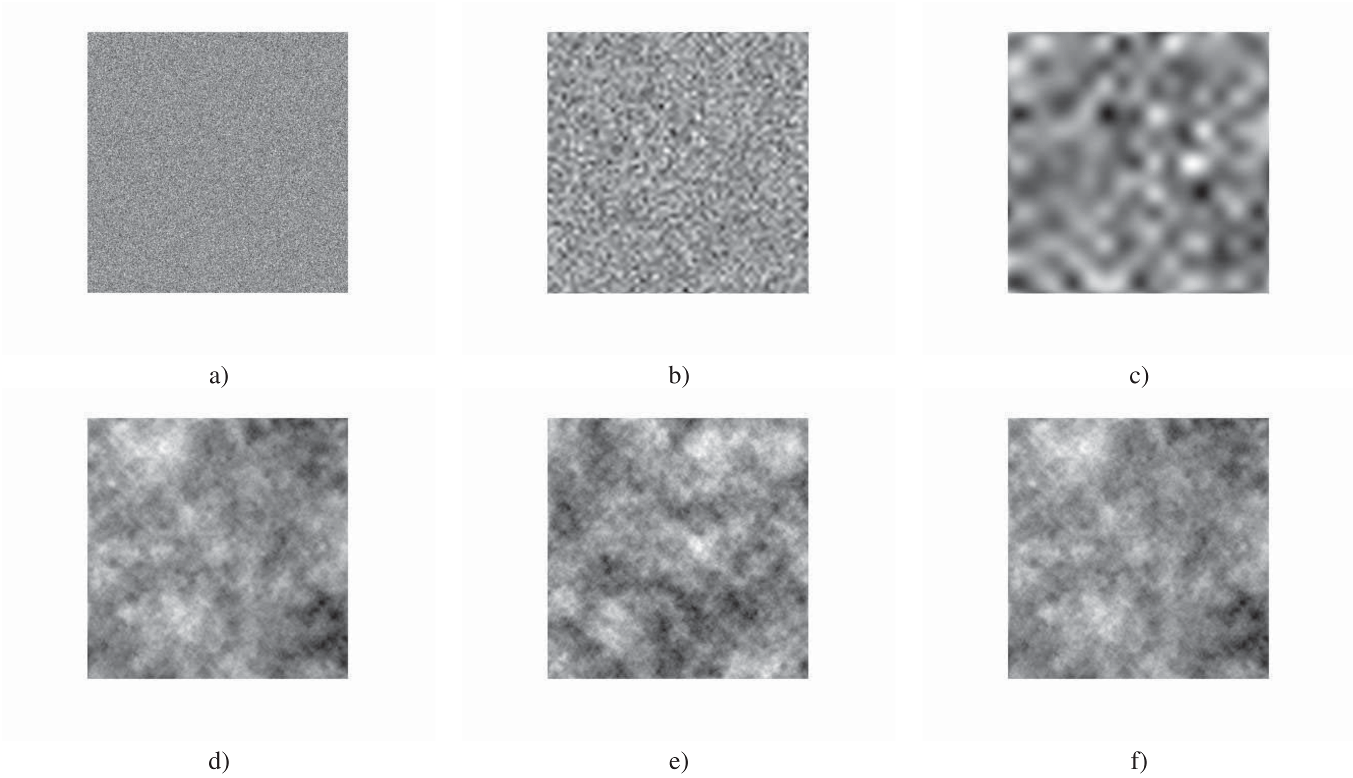


Fig. 3. a-c) Examples of Perlin's noise maps (octaves); d-f) Examples of Perlin's noise images

Examples of results of Perlin's noise calculation are shown on Fig. 3 a-c. Separate noise maps carry the name of octaves as one of them has twice bigger scale, than another. Uniting of octaves by their addition, multiplication, etc. leads to formation of new noise templates (Fig. 3. d-f). The additional processing is necessary after imposing of Perlin's noise image for obtaining effect of dirt. Processing consists in narrowing of the histogram and formation of two textures: alpha channel and texture of color. The proportion of area filled by noise to the area of all license plate is used as a critical parameter for designation of a noise level. Depending on this parameter the histogram of the image is narrowed by the method of bisection. Then the image of noise is transformed from monochrome to the color image by means of the table of colors.

III. COMPARING VERISIMILITUDE OF SYNTHESIZED IMAGES

A. The analysis of similarity between the synthesized images and photos of car license plates

The base of photos consisting of 98 images was made before comparison of the synthesized images with photos. The camera angle was chose to each photo in a three-dimensional scene (Fig. 4).[4]

The texture features received by means of an adjacency matrix are used for comparison of the synthesized images and photos. The brightness levels adjacency matrix, or occurrence matrix (Gray Level Co-Occurrence Matrix, GLCM) is the two-dimensional array in which indexes of lines and columns form a set of values of brightness, allowable after the quantization procedure. Values of a matrix are defined as follows [5]:

$$c(i,j) = \sum_{p=1}^{N}\sum_{q=1}^{M} \begin{cases} 1, & \text{if } I(p,q)=i,\ I(p+\Delta x, q+\Delta y)=j \\ 0, & \text{else} \end{cases},$$

However the received matrix is not invariant to the image size and it can influence on calculation accuracy very strongly. Therefore before its usage it is necessary to do a normalization:

$$\overline{c(i,j)} = \frac{c(i,j)}{\sum_k \sum_l c(k,l)},$$

On the basis of a normalized adjacency matrix can be calculated more than 20 statistical features. In most cases these features have difficult and not measurable meaning. There are the most popular of them, which are used most frequent in practical realization:

The contrast measure:

$$T_1 = \sum_{i,j} |i-j|^2 c(i,j),$$

The uniformity measure:

$$T_2 = \sum_{i,j} \frac{c(i,j)}{1+|i-j|},$$

The energy measure:

$$T_3 = \sum_{i,j} c(i,j)^2,$$

Fig. 4. Example of camera angles conformity

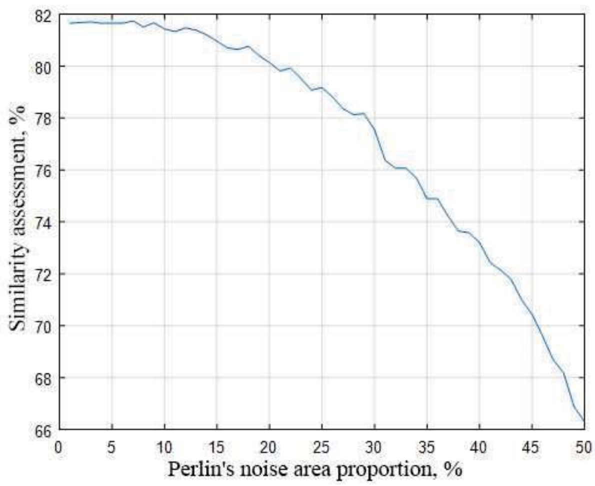


Fig. 5. Similarity assessment by textural similarity depending on Perlin's noise area proportion

The correlation measure [6]:

$$T_4 = \sum_{i,j} \frac{(i-\mu_i)(j-\mu_j)c(i,j)}{\sigma_i \sigma_j},$$

The method of similarity definition between the original image and the duplicate one consists of the following stages:

1) Choosing from car license plates photo collection one (original).
2) Choosing from synthesized images collection the duplicate photo with a certain level of a noise.
3) Adding the duplicate image to a collection of 99 random images which don't contain car license plates.
4) Calculating the distance between the original image and the received image collection containing 1 duplicate and 99 random ones.
5) Sorting a collection of images in increasing order of Euclid distance to the original image. A similarity mark is given depending on the location of the duplicate in image collection.

The result of similarity assessment on textural similarity depending on Perlin's noise area proportion is presented on the Fig. 5. According to the schedule it is clear that the greatest degree of similarity is observed at values of a Perlin's noise area proportion of to 15%.

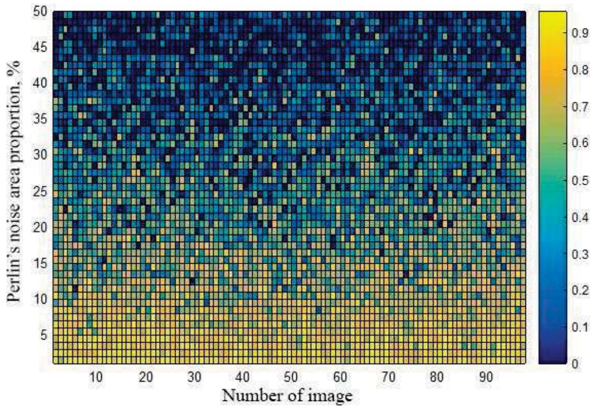
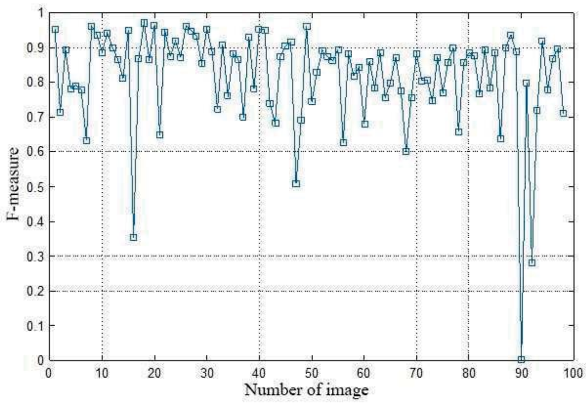


Fig. 6. A surface of a F-measure of the synthesized images (top view)

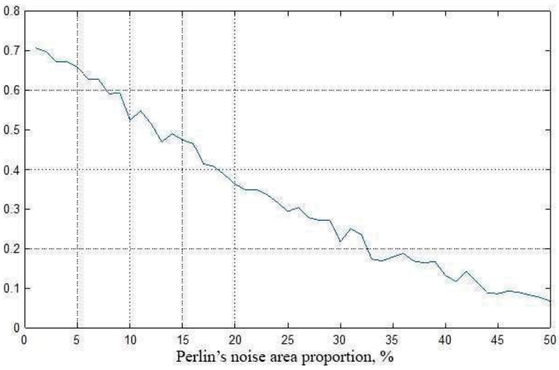
It is necessary to consider that camera angles are not absolutely coincide, and there are other types of distortions on photos: nonuniform illumination, patches of light, various level of contrast etc.

B. Comparing the synthesized images by a segmentation algorithm based on the cellular automaton

Level of similarity of the synthesized images and photos besides comparison of various signs can be estimated by the



a)



b)

Fig. 7. a) F-measure of the photos b) correlation of F-measures

algorithm. If they are equal anyway, then it is possible to consider that the synthesized image is similar to the photo.

For allocation of text symbols on the plate the sequence from operations of cellular automatons is used, each of which carries out a specialized task. Cellular automatons are started in the set sequence, and each next stage begins work in the field, which was created by the previous cellular automaton.

General view of the used algorithm:

1) On the initial image the centers of crystallization which are presumably belonging to the allocated areas are put. Local minima meet a condition of finding of the center in uniform area.
2) Then the centers of crystallization are divided into two classes by Otsu's method: on black and white cages.
3) Black cages which are at an image edge are eliminated.
4) Further from the centers of crystallization growth of areas, i.e. accession to already available points of area of next begins.

Comparison of the segmentated image with the reference marking made by the person is the cornerstone of comparison of similarity of images. [8], [9], [10], [11], [12], [13], [14]

As a rule, the method of a F-average is applied to selection, but not to the only example. However in this case the set of pixels which were carried to this or that object and as far as this set coincides with the set determined by way of a reference marking is estimated.

$$F = 2 * \frac{Precision * Recall}{Precision + Recall}$$

The more the F-measure, the more algorithmic segmentation corresponds reference, and the quality of segmentation of this image is higher.

In Fig. 6. and Fig. 7. the result of work of a segmentator in photos and the synthesized images is presented. The result of work of a segmenator is considered good at the F-measures values close to 1.

Then correlation between a F-measure of photos and a surface of a F-measure of the synthesized images was made. Follows from the schedule that the best coefficient of correlation is 0.7 (Fig. 7).

C. The analysis of similarity between the synthesized images and photos with usage of the recognition system "Auto-Control"

There is a demoversion of the program "Auto-Control" of the company "ELVIS" for recognition of car license plates on separate images in free access. Restriction of demoversion is providing only the visual information in result of recognition. Restrictions of recognition system "Auto-Control":

- Supported formats of files are BMP, GIF, JPEG, PNG, TIFF (full shots with progressive scan).
- Restriction for the image size is multiplicity of image width to four.
- Types of the recognized numbers are standard one-line Russian numbers (a white background, black symbols) with a three-digit code of the region.
- The field of recognition is all image.
- Height of big symbols on license plate is 14-27 pixels.

Taking into account the restrictions described above the base of synthesized images which aren't correlating with photos was created.

The result of work of the system "Auto-Control" on the synthesized image base is given in the Fig. 8. For definition of depending from Perlin's noise area proportion 100 synthesized images were used.

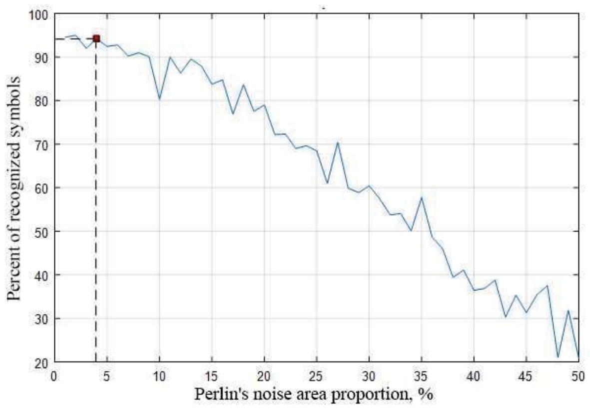


Fig. 8. Dependence of work of the system "Auto-Control" from Perlin's noise area proportion

From the point of view of algorithm "Auto-Control" work on real photos it corresponds the synthesized image base from Perlin's noise area proportion in 4%.

IV. Conclusion

The base formation algorithm of the synthesized images allow to receive for a short time base of any quantity images. It is developed for training and the recognition systems analysis of the car license plates. Experiments of similarity of base synthesized images with photos were given.

On the basis the experiments the conclusions were drawn:

1) The developed algorithm allows to form the image of the plate in 5 seconds whereas on a photo marking at the user 1-2 minutes leave.
2) On the basis of global signs the measure of similarity of the synthesized images with photos is calculated, and assessment of similarity makes within 70-80 %
3) The correlation coefficient between F-measures of work result of the segmentator on the synthesized images and photos is calculated. The best coefficient of correlation give us 0.7.
4) The base of the synthesized images from shares of the area of Perlin's noise in 4 % corresponds to the existing base of photos from the point of view of the "Avto-Kontrol" algorithm work.

On the basis of the received results it is possible to draw a conclusion that the synthesized images from the point of view of global metrics and system of recognition "Avto-Kontrol" are similar to photos. And further the synthesized images can be used as replacement to photos. But at present at the synthesized images the following problems are observed: number plates turn out too contrast, is observed accurate edges at symbols.

These problems can be solved with the help of additional processing of the license textures and ready image. It is also necessary to consider other types of distortion, such as uneven illumination, existence patches of light, deformation of number, etc.

It should be noted that the algorithm of formation of the synthesized base is applicable not only to the car plates. The same mode it is possible to synthesize other objects, but this object has to be rather simple.

Acknowledgment

We would like to show our gratitude to Yuriy Brjukhanov and Vladimir Volohov for sharing their pearls of wisdom with us during the course of this research.

We thank Vera Kokovkina for her help with translation.

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