Allocation of Text Characters of Automobile License Plates on the Digital Image

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***Abstract*—Computer vision algorithms become part of our everyday life. Often they care about safety and control of law and order. Now it sufficiently important task in Russia so, the article discuss of development this system to recognize Russian standard car numbers. For successful operation it is necessary to develop computer vision algorithms, adaptive to changing external conditions. Among the large number of such conditions, this article describes only the specific application for automatic license plate recognition. In the article this problem is solved with minimal use of a priori information about the object.**

I. INTRODUCTION

Solving the problem of traffic safety improvement and improvement of situation on the roads allows the introduction and employment of intelligent transport systems. They are the sets of interconnected functional systems, such as information gathering systems with traffic detectors and cameras. The techniques used in their creation can be very different due to the diversity of external conditions in which they work [1]. However, all existing devices are composed of two main parts: the part of gathering the image and the part of its subsequent analysis, the results of which are largely determined by the quality of images taken from the camera.

Typically, the analysis consists of three main steps: license plate detection, segmentation of individual symbols on the selected plate and its subsequent recognition. Despite the outward simplicity of the problem, license plate symbols recognition involves solving of non-trivial issues, which is evidenced by the large number of approaches and scientific publications. However, the ideal conditions are rare in practice.

Need reduce the usage of a priori information about the properties of license plate: its size, aspect ratio, etc when constructing an algorithm that can detect the correct license plate area on the image. The usage of such data severely limits the appliance of the algorithm, because such a system will work correctly only if the rather number of external conditions are met. Many algorithms for the successful operation requires effective noise reduction algorithms [2, 3]. Rejection of a priori information can guarantee the operation of system in a variety of shooting conditions.

The goal is to develop an algorithm of car license plate detection on the digital image without a priori information about its properties. This is achieved by combining of algorithms for computing image features and machine learning.

II. PROPOSED APPROACH

To achieve this goal need solve the following tasks:

A. Preliminary search

The preliminary search of areas of interest which can be located license plate is held on the received digital image from the camera. Some of them may be false regions which are not relevant to the registration plate (labels for various purposes, grille, headlights, etc.)

B. Descriptors

Man determines the number plate as "a small metal plate attached to the vehicle to confirm its identity". Description of the image areas which are obtained in preprocessing must be in a formalized format. Consequently, there is a need to find a definition license plate based on descriptors that would be known to the system.

C. Classification

For success classification need develop a specific decision rule or a set of decision rules, based on which the decision will be made if the image area is considered the number or not.

III. IMAGE LOCAL FEATURES

Suppose there is a digital grayscale image is proposed, denoting the two-dimensional intensity function through $I(x, y)$. $S(x, y)$ is the expression for the weighted sum of squares of differences between two adjacent portions of the image $I(u, v)$ and $I(u+x, v+y)$:

$$S(x,y)=\sum_u\sum_v w(u,v)(I(u,v)-I(u+x,v+y))^2 . \quad (1)$$

In the expression (1) the function *w (u, v)* is a Gaussian window function, which is multiplied by the sum of squares of differences between adjacent areas. This is done to reduce the noise sensitivity of the algorithm:

$$w(u,v)=\frac{1}{2\pi\sigma^2}\cdot e^{-\frac{u^2+v^2}{2\sigma^2}} .$$

The testing pixel value $I(u+x,v+y)$ can be approximated by a Taylor series as part of the locality:

$$I(u+x,v+y)\approx$$
$$\approx I(u,v)+\frac{\partial I(u,v)}{\partial x}\cdot x+\frac{\partial I(u,v)}{\partial y}\cdot y.$$

This leads to the approximation

$$S(x,y)\approx\sum_u\sum_v w(u,v)\cdot\left[\frac{\partial I(u,v)}{\partial x}\cdot x+\frac{\partial I(u,v)}{\partial y}\cdot y\right]^2,$$

which can be written in matrix form:

$$S(x,y)\approx(x \quad y)\cdot\mathbf{M}\begin{pmatrix}x\\y\end{pmatrix},$$

where the matrix **M** has the following form:

$$\mathbf{M}=\sum_u\sum_v w(u,v)\cdot\begin{bmatrix}I_x^2 & I_xI_y\\ I_xI_y & I_y^2\end{bmatrix}=$$
$$=\begin{bmatrix}\langle I_x^2\rangle & \langle I_xI_y\rangle\\ \langle I_xI_y\rangle & \langle I_y^2\rangle\end{bmatrix}. \quad (2)$$

In the expression (2) the square brackets denote the averaging operation (summation over u and v within the locality of the current pixel). The matrix **M** is called the matrix of Harris [4].

A diagram showing the cases considered is on Fig. 1.

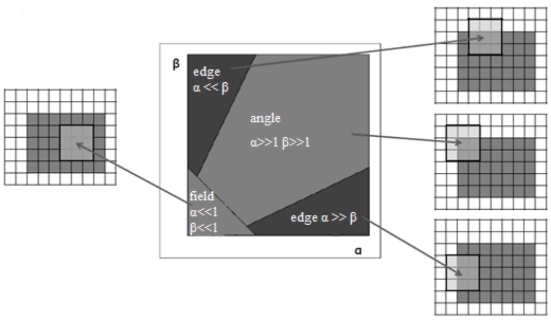

Fig. 1. The relation between types of point features of the image and coefficients α and β

The angle at the point (x, y) (or, in general, feature point) is characterized by a large value *S(x, y)*. About how great it is, can judge on the basis of the analysis of the own values of Harris matrix. They are denoted as α and β, then the value of S(x, y) is proportional to each of them. According to this there is one of the following cases:

- α ≈ 0 and β ≈ 0. In this case, the magnitude of the weighted sum of squares of differences between two adjacent portions of the image is sufficiently small, the considered pixel is in the region of uniform intensity and hasn`t a local feature point [4, 7].
- α ≈ 0, β is a sufficiently large positive number. The magnitude of *S(x, y)* is small along one of the directions, but great on another one. In this case, the intensity of image has gradient along one direction. This indicates about the detection of the region.
- α and β are positive integer values. In this case, a fairly strong change of image intensity along all directions is observed. It says about finding of a point singularity by the type “angle”.

Thus, for detecting characteristics of the image point is necessary to determine the own values of Harris matrix [4]. However, the operation of its counting has a high computational cost. In this case, the following relations:

$$\det(\mathbf{M})=\alpha\cdot\beta,\ \mathrm{trace}(\mathbf{M})=\alpha+\beta,$$
$$R=(\alpha\cdot\beta)-k\cdot(\alpha+\beta)^2=$$
$$=\det(\mathbf{M})-k\cdot\mathrm{trace}^2(\mathbf{M}). \quad (3)$$

The value of the parameter k in the formula (3) can be calculated empirically. This response function is a two-dimensional function of pixels coordinates and it is called a Harris angles map [4]. The value of *R* is positive in the region of angle and is negative in the regions with uniform intensity.

IV. DETECTION ALGORITHM

Knowing the map of Harris detector responses, on which all detected point features of the image are marked, start looking for those areas that may be the license plate of the car.

By combining multiple operations into a sequence of actions, we can formulate the main stages of the proposed algorithm:

1) Operations of binarization: for grayscale image of responses map. In practical terms it is convenient to select automatically binarization threshold (without user intervention) [5]. For this can be used a variety of methods: k-means algorithm, the peaks search in the histogram, Otsu method, various algorithms of local binarization of the images.

2) Search and labeling of related regions: At the beginning there is the search and labeling of related regions of binary image with the help of a search algorithm for related components. Further it is selected only one of this regions which have to be the license plate of the car, the which is selected by means of a classification algorithm.

In the algorithms of local binarization [5] the calculation of threshold begins with the decomposition of the original grayscale image into blocks of a certain size, in which information about the intensity of the image is gathered. The size of this local unit should be minimal, but sufficient to keep the local features and details of the image. On the other hand, the block should be large enough to reduce the noise in the result. As part of the local unit of a certain size values of the local average intensity of *m(x, y)* and the local standard deviation δ(x, y) are calculated. Then binarization threshold is calculated for the current local unit:

$$T(x, y) = m(x, y) + k \cdot \delta(x, y)\,. \tag{4}$$

The parameters of the algorithm influenced greatly to the result binarization (the value of the local unit in which the binarization threshold is calculated and the parameter *k* in the formula (4)). His negative values provide separation of black objects from white background, and positive provide an opportunity to distinguish white objects from black background [5]. This is especially important in the binarization of the responses maps of Harris detector, because the loss of an important area or appearance of false area can have a significant impact on the future work of the algorithm of license plate detecting.

V. THE DESCRIPTORS OF CLASSIFICATION ALGORITHM

After binarization of responses maps of Harris algorithm a binary image is obtained in which a several number of related regions is. They correspond to certain areas of the original image. There may be license plate area among them. In order to determine which region is the number the problem of classification of these regions is solved using an algorithm of anomalies detecting. For this region characteristic features (such as the histogram of oriented gradients) are calculated. During building such type of descriptors it is important to set their parameters, such as the number of cells used in the histograms [6]. Histogram normalization operation within blocks of cells provides invariance to photometric transformations, such as changing the brightness and contrast of images.

Final stage of the HOG-descriptors calculation is to obtain the feature vector. It is calculated by combining all the elements of the normalized histogram blocks. On Fig. 2 if is schematically illustrated the process of computing HOG-descriptors [6].

Currently, there is a large amount of machine learning algorithms capable to implement separation between the classes themselves. To solve the problem of binary classification algorithm of anomalies detection is used [7]. A possibility of learning only on the positive cases is key feature of this algorithm. Then all positive answers will provide a significant response, while the opposite situation will all be at the level of random fluctuations.

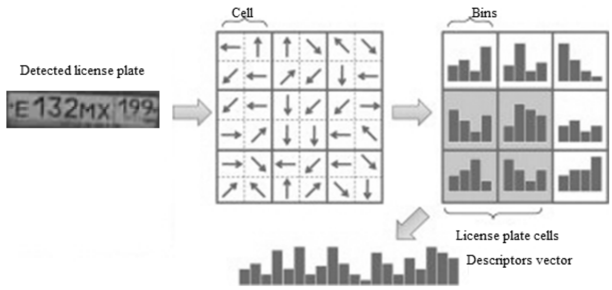

Fig. 2. Calculating scheme for the HOG-descriptors

VI. RESULTS AND TABLES

For rating the performance of the algorithm the method of detecting the error curve or ROC-curve (Receiver Operation Characteristic) is used [8]. It is a characteristic curve of a binary classifier. This is a ratio of the level of true positive classifications to the level of false positive classifications by varying the threshold of the decision rule.

The level of true positive decisions of a classifier (TP) is denoted as $\mathrm{TPR} = \dfrac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}$ (recall, the fullness of the sample), and the level of false positives (FP) solutions - $\mathrm{FPR} = \dfrac{\mathrm{FP}}{\mathrm{TN} + \mathrm{FP}}$, sensitivity of model - $\mathrm{Se} = \mathrm{TPR}$, specificity of model - $\mathrm{Sp} = 1 - \mathrm{FPR}$. Here FN (false negative) is the number of false negative decisions of the classifier, and TN (true negative) is the number of true negative decisions.

From these definitions it follows that the model with high sensitivity gives the true result in the presence of a positive outcome in most cases. Model with high specificity often gives the true result with a negative outcome.

Among the most important requirements to the parameters of the algorithm are:

- a minimum value of the sensitivity of the model (in this case, the optimal threshold value will be the value of model specificity, which is attained at a given minimum sensitivity) ;

- the maximum value of the total sensitivity and specificity $\text{Thresh} = \max_{k}(\text{Se}_k + \text{Sp}_k)$;
- the balance between sensitivity and specificity of the model $\text{Thresh} = \min_{k}\left|\text{Se}_k - \text{Sp}_k\right|$.

ROC-curves quite clearly characterize the predictive ability of the constructed model [8]. Efficiency detection algorithm car numbers can be illustrated in the experiment. To perform this test was used car traffic video on one of the really existing streets. Of the all-time record for consideration portion was taken from the typical characteristics of the movement of vehicles. It considered frames, which contain only car and his number is in the frame entirely. Total in test sample video there were 200 such cases, and which was marked the test database. The resolution was 720 * 576 pixels, which corresponds to a standard definition television. The algorithm is implemented in MATLAB.

The operation of the algorithm with shifting value of the pixel locality is illustrated on Fig. 3a.

The most effective classifiers are described by curves, which are located as close as possible to the upper left corner of the coordinate system. For these three sets of parameters of the algorithm condition is fulfilled, wherein the sensitivity of the pattern was more than 90% in all cases. The best predictive power has a model built using 7x7 localities.

A similar group of ROC-curves is constructed for parameters of local binarization algorithm at different values of pixel units and different values of k. These relations are illustrated in Fig. 3b.

ROC-curve is closest to the upper left corner during using a local binarization with 20x20 pixel unit. Therefore, the model with the following parameters is considered the most accurate among all examined models.

VII. SEGMENTATION

Today the segmentation of the image is based on its information component. Common methods are functionally limited because of the geometry.

It is offered to consider the information contained in the image as the basis for sharing objects and final segmentation of the characters in the text of the content in the automobile license plates. The concept of "cost function" is introduced for definition of information significance. This function is a conditional value that characterizes the importance of a given pixel in the current image [9].

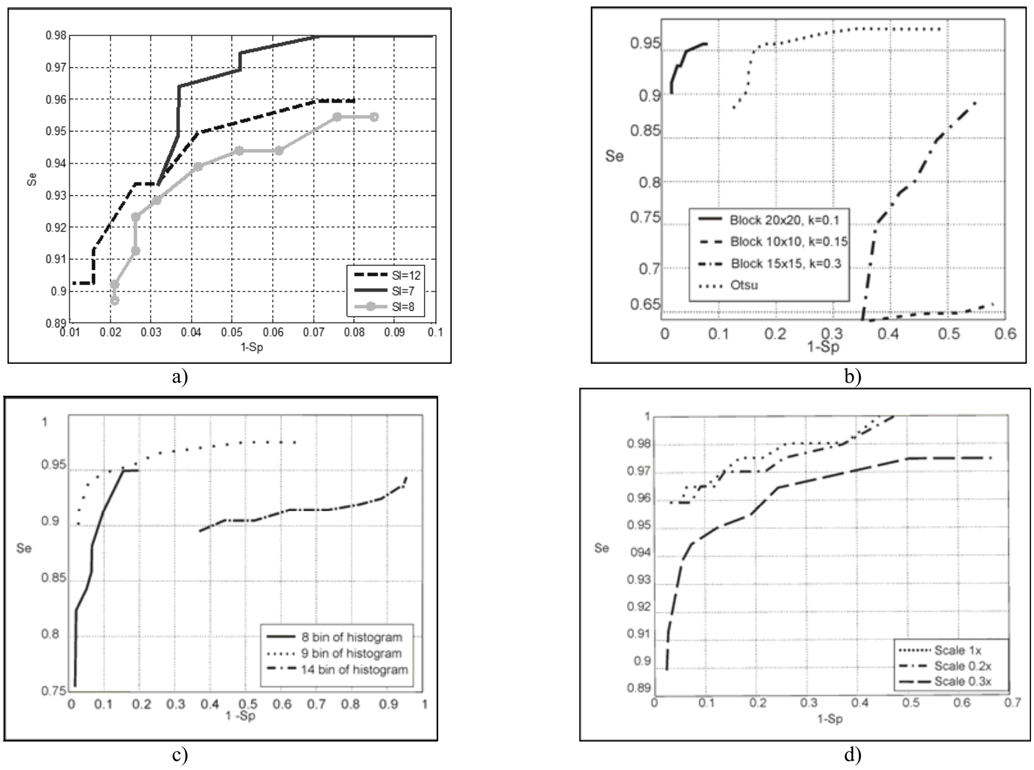

Fig. 3. Groups of ROC-curves

The general scheme of the segmentation algorithm is as follows:

1) Calculation of the energy function for each pixel of the image

$$e(I) = a \times \left|\frac{\partial I}{\partial x}\right| + b \times \left|\frac{\partial I}{\partial y}\right|$$

There are fairly large number of variants of the energy function. The most important elements in the image are the structure and contours of objects, as illustrated in Fig. 4.

Fig. 4. Energy function for the test image

It is necessary to solve the problem of separation of symbols considering energy function. There are several approaches to solving this problem. For example, can specify a condition of maximum energy conservation and separate the pixels with the lowest energy. This approach destroys the structure of closed objects and deforms symbols.

2) Compliance of the condition of related pixels which will be divided into segments is required to prevent the image from damage. All paths are built in the image - 8-connected set of pixels, built in the image upside down. It is illustrated on Fig. 5.

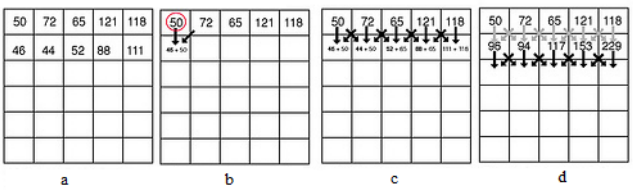

Fig. 5. The principle of calculating the additional weight

The rule for constructing relates regions is formalized as follows:

- The starting point is an image obtained by calculating the energy function (Fig. 5a).
- For the pixel of (n+1) - row extra weight is calculated - the smallest value of the three neighboring pixels in n-row. (Fig. 5b). The general idea of this operation is illustrated briefly on Fig. 6.
- Operation of calculating the weight of the extension is performed for each pixel in (n+1) - row (Fig. 5c). This additional weight added to the current intensity of the analyzed pixel in (n+1) - row.
- The operation is performed for all rows of the image.

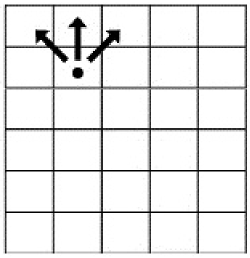

Fig. 6. Definition of related pixels

3) Line formation: In fact, there are the lines along which the energy change within the 8-connected set of pixels is minimal on a modified image. Values of all such paths are evaluated using cost function *e(I)*:

$$E(s) = E(I_s) = \sum_{i=1}^{n} e(I(s_i))$$

Next step there are selected paths with the lowest cost, which will be the dividing lines between the characters:

$$s^* = \min_s E(s) = \min_s \sum_{i=1}^{n} e(I(s_i))$$

Formation of the dividing line character occurs iteratively, in reverse order, as demonstrated by Fig. 7.

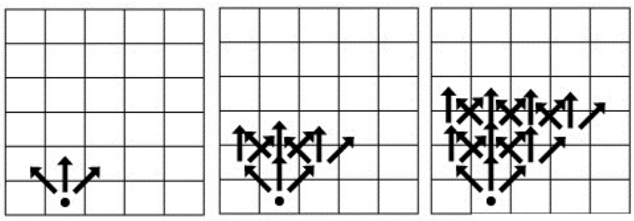

Fig. 7. Possible directions of forming paths

4) Compose vertical chains pixels: for pixels can be applied:

- the total energy function of all pixels of the chain is minimal;
- chain crosses the image upward;
- a chain composed so that it consisted of only one pixel of each line and the adjacent pixels must be connected by the sides and angles.

Illustration of the algorithm on the basis of such a test is shown in Fig. 8.

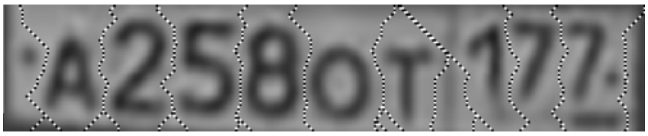

Fig. 8. Formed lines between the symbols

It can be seen that most of the dividing lines between the symbols are correctly performed; each selected segment comprises one symbol. However, in some cases, there are also incorrect results, which should be considered wrong: this is a decal algorithm dividing line and a false alarm. The most common mistake is skipping the dividing line. In this case, the algorithm does not find the line between two symbols.

Thus, during the tests the relations between the specificity, sensitivity and the parameters a, b were calculated. They are illustrated on Fig. 9. As can be seen, these surfaces have common points, crossing on certain curve form. Intersection of these areas will be the parameters a and b, which will be optimal by the ratio between sensitivity and specificity of the algorithm.

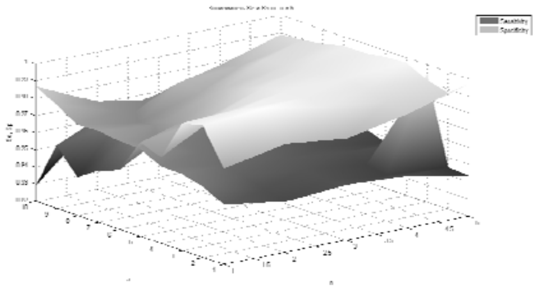

Fig. 9. The dependence of the sensitivity and specificity from the cost function parameters

It is the most favorable ratio between the errors of the first and second kind, and the algorithm will work most effectively. According to this it will be enough to hold the boundary between adjacent characters on the digital image of a vehicle license plate.

VIII. CONCLUSION

It is proposed a combined algorithm of detecting license plates of cars on the digital image, which does not require a priori information about the object. Object is achieved by looking at it the characteristic elements of the singularity by the type “angle”. Additional description of the areas of interest using HOG descriptors that have the properties of invariance to scale and illumination, allows comparing different images. Selected classification algorithm "anomalies detector" allows us to restrict ourselves to the positive examples and thereby significantly reduce the size of the base training. There is an analysis of the dependence of correct detection probability from the different values of the internal parameters using ROC-curves method.

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