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MUNDARIJA | ОГЛАВЛЕНИЕ | TABLE OF CONTENTS

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METHODOLOGY FOR BUILDING LICENSE PLATE RECOGNITION SYSTEMS

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Abstract. This article discusses the importance of automated online recognition of text information, focusing on license plate recognition systems. The benefits of such systems include automating vehicle control at restricted access areas, parking lots, service stations, and highways. The general structure of a typical license plate recognition system is illustrated in Figure 1. The article highlights the role of video cameras as image capturing devices and the restrictions associated with their installation, such as camera tilt angle and resolution. It also mentions the importance of minimum contrast for license plate images and the use of infrared illumination to enhance contrast. Preprocessing steps for the captured images are outlined, including image correction, blurring effect elimination, redundant information elimination, and car localization using a software motion detector. The article emphasizes the continuous improvement and modification of existing license plate recognition systems worldwide.

Keywords: license plate recognition systems, vehicle control, restricted access areas, parking lots, service stations, minimum contrast, infrared illumination, preprocessing steps, image correction, blurring effect elimination, redundant information elimination, car localization, software motion detector.

Introduction

Automated online recognition of text information, particularly in the context of license plate recognition systems, holds significant importance across various practical applications. Such systems play a crucial role in automating vehicle control processes at restricted access areas, parking facilities, service stations, and highways. By seamlessly integrating with existing infrastructure, these systems enhance operational efficiency, facilitate traffic management, and contribute to enhanced security measures.

The necessity for automated license plate recognition arises from the increasing demand for efficient and reliable solutions to monitor vehicle movement and enforce regulations. In this context, this article aims to explore the methodologies and advancements in license plate recognition systems, shedding light on their significance and evolving capabilities.

The discussion encompasses the general structure of a typical license plate recognition system, emphasizing the pivotal role of video cameras as image capturing devices. Various considerations regarding camera installation, such as optimal resolution and angle, are highlighted, underscoring the challenges associated with achieving accurate image capture.

Furthermore, the article delves into the preprocessing steps essential for refining captured images, including image correction, blurring effect elimination, and redundant information elimination. Special attention is given to the utilization of infrared (IR) illumination to enhance image contrast, thereby improving the efficiency of subsequent recognition processes.

Methods

The study aimed to develop an automated system for online recognition of text information, focusing on license plate recognition. The methods employed involved capturing images using video cameras, preprocessing the images to enhance contrast and eliminate redundant information, localizing license plates within the images, and recognizing individual characters on the license plates.

Image Capturing and Preprocessing: Video cameras were utilized as image capturing devices. The cameras were installed with specific optical resolutions to ensure optimal framing of license plates within the captured images. Moreover, the installation angle of the cameras was carefully considered to minimize occlusions caused by nearby vehicles. Preprocessing steps were applied to the captured images, including image correction, blurring effect elimination, and redundant information elimination. Infrared (IR) illumination was employed to enhance contrast, particularly for license plate images.

Localization of License Plates: Two approaches were utilized for localizing license plates within the images: edge detection algorithms and the Hough transform. Edge detection algorithms such as Sobel, Kenny, and Robinson were employed to detect horizontal and vertical edges within the images. A window-based method was then employed to estimate the presence of license plates within the highlighted areas. Additionally, the Hough transform was utilized to detect areas of various shapes, including rectangles, in the images. The transform outputted a set of candidate regions for license plate localization based on the detected shapes.

Character Recognition: Following license plate localization, character detection and recognition operations were performed. Binarization algorithms were used to eliminate redundant information, with the binarization threshold determined based on the brightness histogram of the images. An average intensity projection method was employed to detect individual characters within the binarized images. Geometric constraints were applied to filter out unwanted regions, ensuring only valid characters were retained. Character recognition was achieved using a modified font algorithm, specifically the zone method. This method involved training a reference set of zone descriptions for each symbol and then comparing the zone description of the tested symbol with the reference set to identify the nearest match.

Results

The developed system was evaluated on a dataset consisting of 200 images containing license plates. The system achieved a recognition accuracy of 85% for license plates within the tested images. The performance of the system was assessed based on its ability to accurately localize license plates, eliminate redundant information, and recognize individual characters. The results demonstrated the effectiveness of the proposed methods in achieving reliable license plate recognition in real-world scenarios. Further optimizations and enhancements may be explored to improve the system's performance and extend its applicability to diverse environments and conditions.

The problem of automated online recognition of text information is an urgent task associated with a wide class of practical applications. One of these tasks is license plate recognition. Creating an automatic system that registers license plates allows you to:

• automate control of entry and movement of vehicles at facilities with limited access and closed areas;

• monitor entry and exit to parking lots, automatically calculate the cost of services provided, and control free space;

• automate control of the departure of paid or unpaid vehicles at service stations and car factories, control the load of the service area;

Fig. *1. General structure of a typical license plate recognition system*

• monitor the entry, exit and time spent of vehicles on the territory of the warehouse and terminal, prevent possible thefts;

• on highways, ensure control of traffic flows and carry out automatic tracing of stolen vehicles and those with a record of offenses;

• automate the collection of statistics for municipal services.

Today, there are already several systems for automatic recognition of license plates in the world. All of them are far from perfect and are constantly being modified. However, the general structure and solutions to this problem have already been formed (Fig. 1).

The image capturing device is a video camera. There are a number of restrictions imposed on the installation of a video camera. The optical resolution of the camera is selected so that the number plate occupies horizontally from 25 to 33% of the frame. The maximum permissible vehicle speed at which recognition is possible depends on the angle of the camera to the road surface. The work [1] declares: “The typical camera tilt angle should be 40° so that the car in front does not block the next one,” which also imposes a number of restrictions. The vertical size of the number plate decreases in proportion to the cosine value of the camera tilt angle. Consequently, it is necessary to increase the optical resolution, which leads to a reduction in the width of the field of view. Some license plates can be installed with an inclination towards the road surface. At a large angle of inclination, recognizing such license plates is very problematic. Horizontal installation of the video camera is considered optimal, i.e. at the level where the number plate is located. This installation is used in systems for automatic entry into closed areas, parking, etc.

Another important parameter is the minimum permissible contrast of the license plate image. In some systems, an additional module is installed, consisting of infrared illumination and a corresponding filter [2]. This approach allows you to increase the contrast of the license plate in relation to the rest of the image. This technology is based on the fact that the license plate has a special reflective coating, in which the reflected light propagates in the opposite direction to the propagation of the incident light (i.e., the angle between the incident and reflected beam is 0°), due to whereby the camera will perceive mainly infrared light and light reflected from the license plate (Fig. 2). The picture in this case will be monochrome without details, with the exception of the license plate.

Preprocessing of the resulting image includes the following steps.

1. Image correction – equalization, limitation of extreme brightness values, modification of the brightness distribution histogram.

2. Elimination of the image blurring effect that occurs due to the fact that the vehicle speed is greater than the registration speed (shift compensation).

3. Elimination of redundant information – use of infrared (IR) illumination, binarization, splitting the image into separate color regions.

4. Using a software motion detector to localize the car in the image.

Fig. 2 Image preprocessing: a) original image, b) using IR illumination, c) binarized image

The disadvantage of preprocessing with binarization is that the selected binarization threshold does not provide the required quality for any type of image. Factors such as lighting or even the color of the vehicle affect the quality of the image binarization. The use of adaptive binarization methods, however, makes it possible to solve this problem more qualitatively.

One of the approaches used to localize the license plate is the method of detecting image boundaries using algorithms such as the algorithm of Sobel, Kenny, Robinson, etc. [3]. The edge detection algorithm must detect both horizontal and vertical edges. The resulting image, after highlighting the edges, should contain a large number of lines in the area of the license plate plate, since it contains symbols. This is the main property that is used to highlight the license plate area in the image.

To localize the license plate area, a window is created approximately equal to the size of the license plate plate in the image. This window is used to estimate the number of edges in all areas of the image that have the greatest contrast. The window is superimposed on the resulting image in the most contrasting areas. If the number of edges is in the specified range, then this area is marked as an area that may contain a license plate. The required number of faces is determined experimentally.

But. The result of this window is a list of possible candidate areas that may contain a license plate plate. The disadvantage of this approach is that the candidate selection process is slow, since the values of all pixels in the selected window must be summed repeatedly. Another disadvantage is the recruitment of a large number of license plate candidates.

An alternative approach for license plate detection is the Hough transform, which is used to detect areas of various shapes in an image, such as a circle, ellipse, straight line, etc. [4]

The input of the Hough transform is a binary image with vertical and horizontal selected edges. At the output of the transformation, we obtain a set of straight lines that limit the proposed license plate, that is, a list of possible candidates for the location of the license plate plate.

The Hough transform algorithm for straight line detection is as follows.

1. Selecting the starting pixel A(x,y).
2. Selecting the final pixel B(x,y).
3. Counting binary image points along line AB. rectangle describing the car number
4. If the number of counted pixels is greater than the specified threshold value, then the AB line is present in the image and is marked.
5. Return to step 1 and select two more pixels until the last image point is reached.

Horizontal and vertical pairs of lines are compared. Horizontal and vertical pairs of lines that make up a rectangle with a ratio of sides approximately equal to the ratio of the sides of the number plate are marked as an area possibly containing a number.

One of the disadvantages of the Hough transform is the fact that the vertical lines on the license plate are much shorter than the horizontal ones and, therefore, can be noisier.

Once the license plate has been localized, the character detection operation is performed. To eliminate redundant information, a binarization algorithm is used. The threshold is selected in the algorithm based on the brightness histogram of the image, which is a one-dimensional array H[0.255], each cell of which contains the number of image points with intensity value I.

According to observations, a license plate has the following property: the average area of all symbols is about 23% of the area of the entire license plate, which is rectangular in shape. For different numbers, deviations from this value do not exceed 5%. In this case, the binarization threshold T can be determined by the following expression $\sum_{j=0}^{T-1} H[j] \approx 0,23S$, where S is the area b of the rectangle describing the car number. The result of this algorithm is presented in Fig. 3.

Fig. 3. Binary image

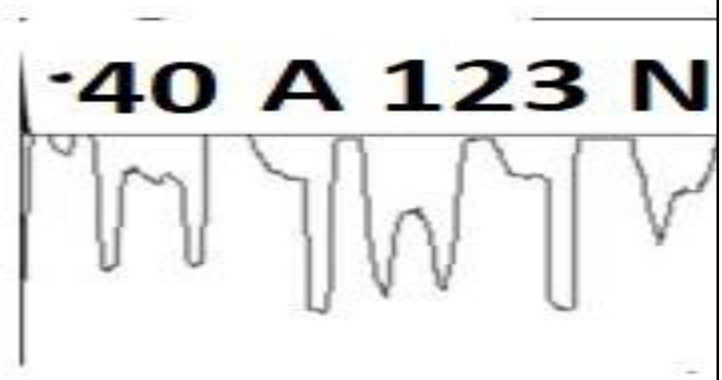

Fig. 4. Horizontal projection (average intensity distribution) of the number plate

The next step is to search for individual characters. For this purpose, we use a method based on constructing an average intensity projection (Fig. 4). The essence of this approach comes down to the following:

the average intensity in each column is calculated, and in places where there is no symbol, the average intensity will differ significantly. Then, performing the same operation on lines, a set of individual characters is obtained that can already be recognized.

After performing this operation, we can receive both symbols and various interference that need to be eliminated. This is achieved by checking a number of conditions that the symbol must satisfy as a geometric object.

First, the dimensions of the rectangle describing the candidate region are calculated. Checking the condition $0.9 \leq a/b \leq 3.5$ is met, where a and b are the width and height of the object, respectively. Objects that do not satisfy this relationship are discarded from consideration.

Secondly, the fulfillment of conditions is checked; those that do not satisfy this relationship are discarded from consideration.

Secondly, the fulfillment of the condition 0.4 □ b/h □ 0.9 is checked. where h is the height of the rectangle, describing the car number. This relationship imposes a limit on the minimum and maximum height of characters in relation to the height of the number.

Finally, the third condition aims to remove small areas of no interest. Among the objects that satisfy the above-described

Under certain conditions, an object with the maximum area of the describing rectangle Smax=a x b is selected. Then, among the remaining areas, those are selected

which satisfy the condition S/Smax □ 0.1, where S is the area of the rectangle of the candidate object.

Checking these simple conditions allows you to eliminate all unnecessary objects, selecting only eight digits of the number (Fig. 5).

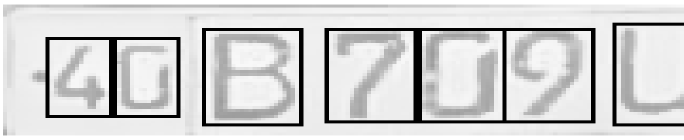

Fig. 5. Highlighted characters

Since the license plate contains a limited set of characters in a fixed font, in this case it is advisable to use a font recognition algorithm. The principle of operation is based on direct comparison of the symbol image with the standard. The degree of dissimilarity is calculated as the number of mismatched pixels. To ensure acceptable accuracy of the template method, preliminary image processing is required: normalization of the size, slope and thickness of the stroke. The standard for each class is usually obtained by averaging the symbol images of the training set.

This method is easy to implement, works quickly, is resistant to random image defects, but has a relatively low accuracy. Widely used in modern character recognition systems.

To recognize characters, we use one of the modifications of the font algorithm – the zone method [6]. This method is based on comparing the zone representation of a symbol image with a reference set of zone representations of symbols. Therefore, the recognition algorithm consists of three main procedures: training, loading a set of reference zone descriptions, and recognition.

At the training stage, a complete reference set of binary images of symbols, images of all valid symbols, was used. In this case, for each reference image in the set the following actions were performed.

• Determine the minimum rectangle containing all black pixels.

• Uniform division of the frame into *N*□*M* rectangular zones.

• Counting the number of pixels belonging to each

doy zone.

Formation of a zone description vector consisting of the number of black pixels for each zone, normalized by dividing by the total number of black elements of the entire image.

The number of pixels belonging to each zone is counted by voting black pixels. In this case, each pixel is considered as a square of size 1□1, the position of the zone boundaries is calculated with subpixel accuracy, and each black pixel votes in favor of those zones with which it intersects, with a weight equal to the intersection area.

As a result of the training stage, for each symbol, a zone description file, a symbol name in ASCII code, and a zone description vector of size N□M with elements of float type are generated. The zone description vector is written line by line, from left to right, top to bottom.

When loading reference data, the reference file is read and a corresponding list of reference vectors of zone descriptions is generated.

When analyzing each symbol, the following operations are performed:

1. formation of a zone description vector;
2. formation of a distance vector;
3. symbol classification based on the distance vector.

The formation of the zone description vector is carried out as described earlier for reference images.

The formation of a distance vector involves sequential calculation of Euclidean distances between the vector of the zone description of the tested symbol and the vectors of zone descriptions of each standard in the list. Classification of a symbol is carried out by analyzing the distance vector and selecting the “nearest neighbor” among the standard zone descriptions.

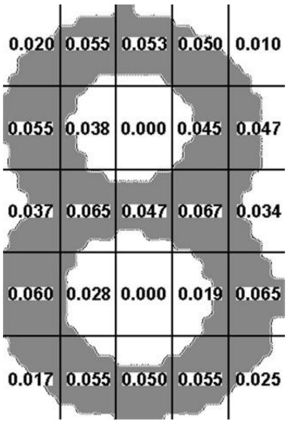

Fig. *6. Reference image of the symbol “8”*

Taking into account the structure of the strokes of the characters, for the size of the character images of the order of 10□15 pixels, the optimal number of zones will be N□M, where N=5 and M=5. With this choice of zone resolution, the used method of normalizing the zone description vector makes it possible to ensure the stability of this recognition method to changes in the thickness of symbol strokes due to instability of the brightness characteristics of the image.

In Fig. Figure 6 shows the reference image of the symbol “8”, the division into zones and the pixel weights of each zone.

The sequence of algorithms described above was used to create a program for searching and recognizing license plates. The program was developed in the Delphi 7 environment and tested on 200 images, the probability of recognizing a license plate was 85%.

Conclusion

In conclusion, the study provides valuable insights into the realm of automated license plate recognition systems, highlighting their pivotal role in modern traffic management and security operations. Through the utilization of video cameras and sophisticated preprocessing techniques, these systems enable efficient capture and processing of license plate images, facilitating seamless vehicle monitoring and control. Moving forward, ongoing advancements and refinements in license plate recognition technology are anticipated, paving the way for enhanced functionality and reliability. Future research endeavors may focus on addressing existing limitations, such as improving recognition accuracy under challenging conditions and optimizing system efficiency for real-time applications. In essence, automated license plate recognition systems continue to evolve as indispensable tools in modern transportation infrastructure, offering unparalleled capabilities for efficient vehicle management, security enforcement, and traffic monitoring.

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