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TRAFFIC SIGN DETECTION AND RECOGNITION USING SINGLE SHOT MULTIBOX DETECTOR

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Abstract—The article is devoted to the automatic detection and recognition of traffic signs system design which processes the images received from the vehicle digital video recorder. The digital video recorder is used both for its intended purpose and to include it in the process of driving, facilitating the driver's work and, thus, significantly increasing safety and driving comfort. The analysis of the solution of the problem of detection and recognition of traffic signs based on the use of convolutional neural networks is carried out. It is shown that the greatest advantage from the point of view of the criteria of accuracy and speed of response has the single shot multibox detector method. The learning of neural network is done based on traffic signs (adopted in Ukraine) learning sample The study showed that the proposed approach for all used datasets gave both the best recognition quality and maximum performance.

Index Terms—Traffic signs; convolution neural networks; image recognition; single shot multibox detector method.

I. INTRODUCTION

To reduce the risk of drivers and pedestrians nearby, special means have been taken to regulate traffic on the road and thus ensure safety for all road traffic users. One of these meanswas the installation of road signs and signs above the roadway.

As the traffic signs themselves do not perform any functions other than message of certain information to traffic users, all responsibility for traffic safety lies on the drivers. They must follow the rules and restrictions set on this part of the route and decide how to act after danger warnings. In this system, in the absence of unforeseen circumstances, the only problem is that you need to trust that the driver will be attentive and responsible. Achieving this condition becomes more difficult if you take into account the fact that in addition to traffic signs, drivers have to monitor many other factors and features of the road, which is physically difficult, especially on long journeys. Given that speeding is the most common of all causes of road accidents, reducing the impact of the human factor in this system can lead to a significant reduction in the number of accidents.

A significant part of road accidents (PRA) occurs due to the physical inability of drivers to analyze all the information obtained while driving. This problem can be solved by sharing responsibilities by creating systems that will analyze some of this information and thus make driving more comfortable for drivers. One of these systems is the system of finding and recognizing road signs.

If the driver entrusts the search for traffic signs to the program, he will be able to more closely monitor other factors on the road. Thus, he can without distraction monitor the movement of other vehicles and respond in a timely manner to emergencies that occur through the fault of the drivers of these vehicles or for reasons that cannot be foreseen, such as landslides and road destruction.

Given the high risk of accidents from non-compliance with traffic rules (TR) and ignoring road signs, the introduction of this system will significantly increase safety for all road users, not only for those in vehicles, but also for ordinary pedestrians.

Fast and reliable automatic detection and recognition of traffic signs in real time can facilitate the work of the driver and thus greatly improve the safety and driving comfort.

As a rule, traffic signs provide the driver with a variety of information to navigate safely and efficiently. Therefore, automatic traffic sign recognition is essential for automated intelligent driving of a vehicle or for a driver assistance system.

However, identifying traffic signs in different viewing conditions against a natural background is still a challenge.

The purpose of this work is to create a system using a digital video recorder (DVR), which is used in the car, but for other tasks.This system will recognize traffic signs on the road and notify the driver of their presence, and which will reduce the impact of the human factor. This will allow drivers to pay more attention to factors that are difficult to predict, such as the movement of other cars.

The system must find traffic signs and identify them correctly. The input will be a video stream, which is recorded in real time from the DVR located on the front of the vehicle, this stream is processed frame by frame and displayed on the screen with selected signs that have been identified by the system.

Unfortunately, the traffic signs will not look the same in the images taken from the DVR. This is due to the following factors:

- *lighting.* The change of time of day and different weather conditions affect the lighting of objects. This is a serious problem, because colors are represented by numerical values, and changes in lighting lead to a significant change in these values;
- *location relative to the DVR and the road.* Not all signs are perfectly perpendicular to the road, they can be tilted to the side. In addition, they can be reversed in other directions. Because of this, the proportions of the signs themselves are different, which makes it difficult to recognize them;
- *obstacles and shadows.* Roads are not always empty and possible obstacles may partially obstruct the signs. Such obstacles may include tree branches that may not obscure the sign but cast a shadow on it, or snow and dirt that adheres to the surface of road signs.

Due to all these factors, two different images of the same sign, which, for example, can be taken at different angles, will be very different, and a direct comparison will not match. It is better to use machine learning technologies, namely to implement a neural network, which will recognize and classify signs.

II. The Need for Recognition of Road Signs

The operation of the road sign recognition system is that an image is obtained from the DVR, which is then analyzed and the result is returned: the sign is found or not.

For this system it will be more expedient to use a mobile DVR, because recording and processing must take place while the car is moving.

III. Overview of Road Sign Recognition Systems

Many manufacturers have implemented a traffic sign recognition system in their cars. This system is part of the Opel Eye system in Opel cars [1]. Along with it, the Opel Eye supports lane departure warning technology. Mercedes-Benz also has a system to ensure safety in their cars – Speed Limit Assist [2]. The system implemented in Volvo cars is called Road Sign Information [3].

The principle of operation of the Opel Eye system and Speed Limit Assist [1], [2] is as follows: the camera is mounted on top of the windshield of the vehicle, this location allows you to see everything that should be visible to the driver: the road, road signs, other vehicles, various obstacles and pedestrians. This system can recognize a road sign at a distance of up to 100 m. The camcorder has a wide viewing angle and captures video in high quality. This camera captures up to 30 frames per second, which are then processed and checked for signs that are in the database of this system. If such a road sign is detected, information about it will be displayed on the dashboard, this information will disappear only when the restriction indicated by the sign is removed by another appropriate sign.

Road Sign Information [3] automatically detects speed limit signs and displays them in the instrument panel display so you are aware of the current speed limit for the road you are traveling on.

In addition to systems that are integrated into the car, there are also mobile applications. One of these is the RoadAR application, which performs the functions of a video recorder, and which in parallel recognizes road signs on the road and reports their presence.

IV. Structure of the System under Development

The structarial scheme of this system is shown in Fig. 1.

The system for traffic signs detection consists of the following components: a DVR that records images, a computer to which the recorder is connected, and in which image processing and finding and classification of traffic signs takes place, and a screen on which display information about traffic signs that have been detected.

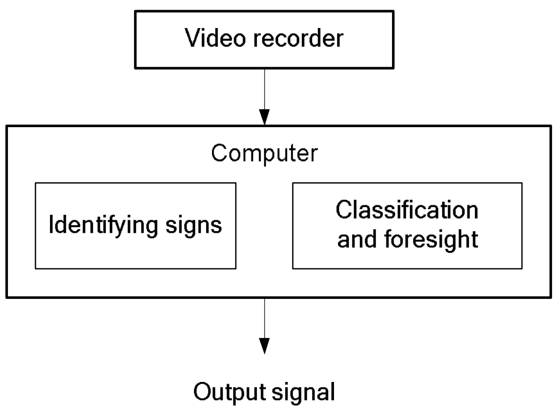

Fig. 1. Block diagram of a system

Images for processing and search will be recorded using a DVR. Digital video recorders do this best because they are designed to record video while driving at high speeds, so the image obtained in this way will be of high quality and will not have the effects of blurring or camera shake. The device will be attached to the windshield, which allows you to see through it, everything in front of the vehicle. Even if the driver does not see any traffic sign, this sign will be recorded by the DVR.

V. PROBLEM STATEMENT OF DETECTION AND RECOGNIITION ROAD SIGNS

There is video data that comes from the DVR in digital form. It is necessary to develop an algorithm for detecting and recognizing road signs that are available on the video information received from the digital video recorder.

VI. PROBLEM OF DETECTING AND RECOGNIZING ROAD SIGNS IN REAL TIME

A considerable number of studies have been devoted to the solution of this problem [4]. In almost all methods in this direction, 3 stages can be distinguished, namely: detection of a road sign, recognition of the shape of a sign and classification [5] – the first two are often combined. There are methods for detecting road signs based on the use of information about their color and shape [6], [7], as well as based on the use of machine learning methods, such as AdaBoost [8], and deep learning [9]. No less important is the problem of classification of detected signs, the quality of which largely determines the reliability of the entire recognition system. Studies carried out in [10] have shown that methods based on the use of deep convolutional neural networks provide high accuracy even in situations with insufficient visibility. This fact is very important for real-time road sign recognition systems, as there are various interfering factors that impede the operation of these systems, for example, perspective distortion, lighting variations, partial blockages, occlusions, as well as bad weather conditions [5].

In recent years, deep learning methods have taken the lead in machine learning due to their effectiveness in solving large-scale problems [11]. The methods of this group have achieved leading indicators in solving most of the problems of computer vision, such as object recognition [12], video classification [13] and scene understanding [14]. These methods have proven themselves well in solving the problem of recognizing road signs [15]. Nevertheless, despite its significant advantages, deep learning methods remain quite computationally and power-intensive. Therefore, many of them are implemented in the form of cloud services [16], which, as noted, introduces additional complications and makes them difficult to apply in real-time systems. These facts greatly complicate the application of these methods in traffic sign recognition systems and require their adaptation.

Currently, the most widespread are combined methods that solve the problem of both selection and recognition of objects.

One of the first such methods was R-CNN (Region-based Convolutional Network) [17]. The main disadvantage of this method is its great computational complexity. Therefore, although the method provides high accuracy, it cannot be applied in real-time systems.

A faster method than R-CNN and SPP is Fast R-CNN [18] (Fast Region-based Convolutional Network). Although the method is faster than R-CNN, it still cannot be applied in real-time systems.

To work in real time, the Faster R-CNN method was developed [19], in which it was proposed to use RPN (Region Proposal Networks) – a special neural network for forming hypotheses. First, the entire image is run through a convolutional neural network, receiving a feature map, then using 3x3 convolution hypotheses (RPN) are formed using "anchors" – rectangles with different aspect ratios and scales. These rectangles are used to localize the search for objects.

A fairly fast method is YOLO (You Only Look Once) [20], but it is less accurate than Faster R-CNN. The method is based on the use of a convolutional neural network. The entire image is covered with a 7x7 grid. For each cell of the grid, two "anchors" are built. The class and the coordinate offset relative to the grid cell are then predicted. Although the method is fast enough, due to the small size of the grid, it does not allow recognizing sufficiently small objects.

The trade-off between accuracy and speed is the Single Shot MultiBox Detector (SSD) multiscale model for detecting visual objects [21]. Such a model performs image detection at various scales using multiple detectors. Each such detector is built on the basis of one of the SNS feature maps (the scale of detected objects increases with increasing network depth). Then, for each of the detectors, a set of "anchor" rectangles ("anchors") is selected - rectangles with different aspect ratios and scales that differ from each other in aspect ratio. The location of the centers of the constructed rectangles depends on the resolution of the feature map and does not depend on the image base on which the network is trained. In addition, the offset of each constructed rectangle from its center is predicted, as well as the degree of confidence that the rectangle covers an object of a given class.

Shot MultiBox Detector performance can be described as follows [22]:

1. The original image goes through a number of convolutional layers, which results in a set of feature maps for different scales (for example, 19x19, 10x10, 5x5, etc.).

2. At each point of each feature map, a 3x3 convolutional filter is applied to obtain a set of circumscribing rectangles.

3. For each rectangle, the spatial displacement and the probability of finding the object are simultaneously estimated.

4. During the training process, the true describing rectangles of the object are compared with the

Unlike R-CNN, where candidate regions have at least a minimal probability of finding an object, SSD has no region filtering step. As a result, a much larger number of circumscribing rectangles are generated at different scales compared to R-CNN, and most of them do not contain an object. To solve this problem, SSDs, firstly, use non-maximum suppression to combine similar rectangles into one. Second, the hard negative mining technique is used [23], according to which only a part of negative examples is used at each training iteration; in SSD, the ratio of the number of negative to positive examples is 3 to 1. The selection of candidate regions and classification are performed simultaneously: For C classes, each enclosing rectangle is associated with a (4 + C)-dimensional vector that contains 4 coordinates and probabilities for all classes. The last step is to use the softmax function to classify objects.

VII. Research Results

Traffic signs in Ukraine follow international patterns, and can be classified into three categories: warnings (mostly white and yellow triangles with a red boundary and information), prohibitions (mostly white surrounded by a red circle and also possibly having a diagonal bar), and mandatory (mostly blue circles with white information) (Fig. 2).

The primary metric of evaluation for object detectors is the mean average precision (mAP). The parameters of the train network is shown in Table I.

TABLE I. PARAMETER SETTINGS

Parameter	**Value**
Learning rate	0.001
Optimizer	adam
Batch size	24
GPU memory fraction	0.9

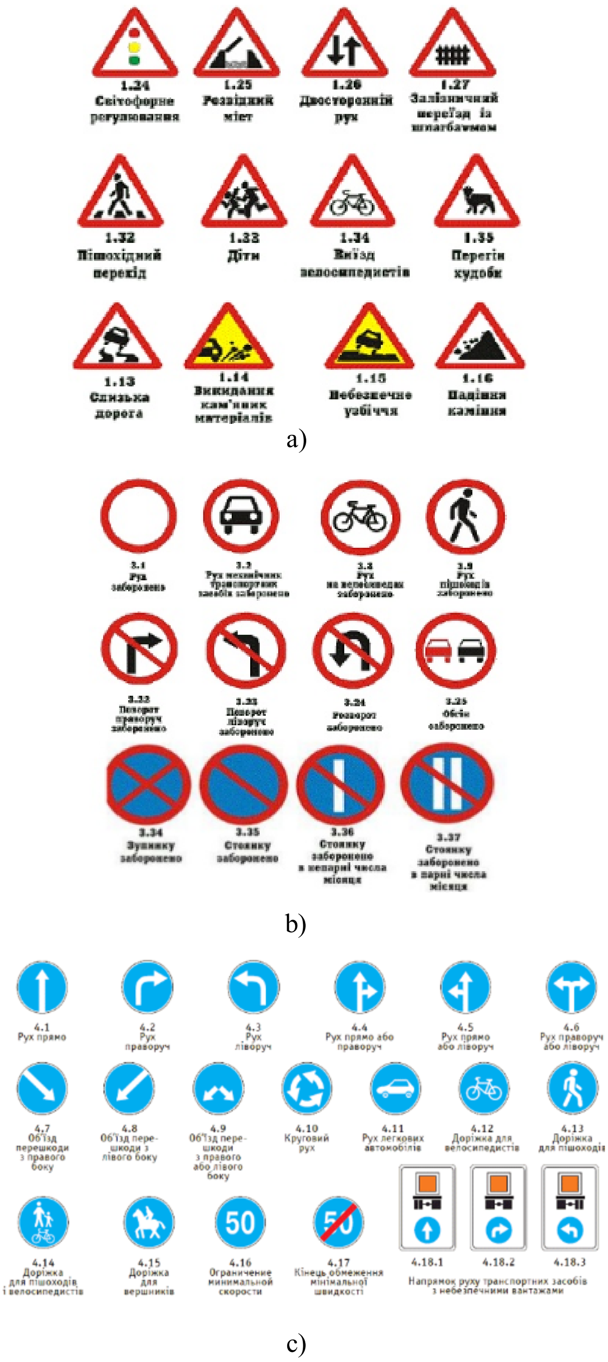

Fig. 2. Road Signs: (a) Warning; (b) Prohibition; (c) Command

Thus, the methods that allow performing the selection and recognition of objects using one convolutional neural network in one direct pass for all hypotheses at once are quite promising. In addition, in order to work in real time without losing accuracy, it is desirable to perform image detection at various scales, based on several feature maps. In addition, it is necessary to choose the optimal sizes of the "anchor" rectangles for the problem being solved using statistical methods, for example, the *k*-means method.

VIII. CONCLUSIONS

The necessity of detecting and recognizing traffic signs has been substantiated.

It is shown that the most promising approach to solving the problem is the use of methods that simultaneously solve the problems of detection and recognition. The main characteristics of such methods are their accuracy and speed of solving the problem, which is necessary to ensure real-time mode. It is shown that this method is the SSD method. An example of solving the problem for road signs in Ukraine is considered.

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О. І. Чумаченко, Л. Б. Петришин, В. В. Кончінскій. Визначення та розпізнавання дорожніх знаків з використанням Single Shot Multibox Detector

Розглянуто побудову системи автоматичного розпізнавання дорожніх знаків, яка виконує локалізацію дорожніх знаків і їх розпізнавання на зображеннях, що надходять з відеореєстратора автотранспортного засобу, що дозволяє використовувати відеореєстратор як за його прямим призначенням, так і включити його в процес управління автомобілем, полегшуючи роботу водія і, таким чином, значно підвищуючи безпеку і комфорт водіння. Проведено аналіз рішення задачі детектування і розпізнавання дорожніх знаків на основі використання згортальних нейронних мереж. Показано, що найбільша перевага з точки зору критеріїв точності і швидкодії має метод single shot multibox detector. Навчання нейронної мережі здійснюється на основі навчальної вибірки, що складається дорожніх знаків, прийнятих в Україні. Проведене дослідження показало, що запропонований підхід для всіх використаних наборів даних дав, як кращу якість розпізнавання, так і максимальну швидкодію.
Ключові слова: знаки дорожнього руху; згорткові нейромережі; розпізнавання зображень; Single Shot Multibox Detector.

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Е. И. Чумаченко, Л. Б. Петришин, В. В. Кончинский. Определение и распознавания дорожных знаков с использованием Single Shot Multibox Detector

Рассмотрено построение системы автоматического распознавания дорожных знаков, которая выполняет локализацию дорожных знаков и их распознавание на изображениях, поступающих с видеорегистратора автотранспортного средства, что позволяет использовать видеорегистратор как по его прямому назначению, так и включить его в процесс управления автомобилем, облегчая работу водителя и,таким образом, значительно повышая безопасность и комфорт вождения. Проведен анализ решения задачи детектирования и распознавания дорожных знаков на основе использования сверточных нейронных сетей. Показано, что наибольшее преимущество с точки зрения критериев точности и быстродействия имеет метод single shot multibox detector. Обучение нейронной сети осуществляется на основе обучающей выборки, состоящей дорожных знаков, принятых в Украине. Проведенное исследование показало, что предложенный подход для всех использованных наборов данных дал как лучшее качество распознавания, так и максимальное быстродействие.

Ключевые слова: знаки дорожного движения; сверточные нейросети; распознавание изображений; Single Shot Multibox Detector.

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