Railway traffic lights recognition system

Aleksandr Belov
Department of the Applied Mathematics
National Research University "Higher School of Economics
Moscow, Russia
avbelov@hse.ru

Maria Belykh
Department of the Applied Mathematics
National Research University "Higher School of Economics
Moscow, Russia
mvbelykh@edu.hse.ru

Shadi Tofayli
Department of the Applied Mathematics
National Research University "Higher School of Economics
Moscow, Russia
shntofayli@edu.hse.ru

***Abstract* — The article deals with the problem of collecting information about railway traffic lights located on the territory of the Russian Federation. To solve this problem, a trained neural network is used that detects railway traffic lights in high-definition images. These images were taken by a camera installed in a train carriage, continuously photographing the area around the track on the right side towards the train. As a result, a detector model of the specified objects was obtained on high-precision images. The paper proposes algorithms for determining the marking and GPS coordinates at a previously detected railway traffic light. The architecture of the information system has been developed, which will have to store complete information about railway traffic lights. The system should be able to quickly search for information and use this data to plan the maintenance of railway traffic lights.**

Keywords— railway traffic lights, neural networks, object detection, information system, computer vision

I. Introduction

Currently rail transport plays an important role in ensuring the delivery of goods. The Russian railway has a long length (it ranks third in the world) and its history begins in the 1830s. Railways are a complex engineering object. It includes various means of automatic control of railway transport. Railway traffic lights are one of the important elements of rail traffic control. A large number of operated railway traffic lights, the difference in their technical characteristics leads to the need to develop an automated system for storing and keeping up-to-date information about railway traffic lights, their technical characteristics, scheduled times for checking and repairing traffic lights. Information about the type of railway traffic light is placed on the identification plate located on the traffic light mast. The data from the marking plate is continuously read from images taken by a camera mounted on a railway locomotive. On the received images, it is necessary to detect the traffic light and recognize the information with a marking plate.

Nowadays, to solve this problem deep learning methods are used. Deep neural networks are currently becoming one of the most popular machine learning methods [1]. They show better results compared to alternative methods in areas such as speech recognition, processing natural language [2], computer vision [3], medical informatics, etc. One of the reasons for the successful application of deep neural networks is that the network automatically extracts from the data important features necessary for solving the problem.

Tasks related to the recognition of traffic signals are considered in works [4, 5]. To detect traffic signals, machine learning methods are used. For instance, in papers[6, 7] the authors solve the problem of detecting the color of traffic lights by using the Adaboost algorithm. Beside detecting objects on images, some authors worked on video object detection [8]. The problem of recognizing traffic lights as railway objects and their labels is relevant. The development of algorithms for recognition of traffic lights and a system for storing information about traffic lights is of practical importance and can be used in transport companies.

II. Problem Statement

In railway transport traffic lights are used as permanent signaling devices. For the detection of railway traffic lights, it is necessary to describe their characteristics. Traffic lights are classified by purpose as [9]:

- entrance - allowing or prohibiting the train to follow from the stretch to the station;

- weekend - permitting or prohibiting the train to go from the station to the track;

- route - allowing or prohibiting the train to proceed from one area of the station to another;

- checkpoints - permitting or prohibiting the train to proceed from one block section (inter-post haul) to another;

- and etc.

One traffic light can combine several purposes (input and output, output and shunting, output and route, etc.). Also, railway traffic lights by location are subdivided into mast, dwarf, and also installed on bridges, consoles, bridge trusses, tunnel walls, and on non-public railway tracks also on the walls of industrial premises.

In this paper the most common traffic lights are detected - dwarf (hereinafter - small) and mast (hereinafter - large).

At a traffic light there must be a marking plate containing its designation. Self-blocking traffic lights are designated by numbers all other traffic lights - by letters or letters and numbers. The type of the marking plate of the railway traffic light is shown in Fig. 1

Fig. 1. Marking plate of the railway traffic light

The problem described in this paper is to detect the railway traffic light and its marking plate to the specific track they belong to. The input receives photos from the front camera installed on the locomotive.

III. Neural Network Model for Railway Traffic Light Detecting

This section describes a method for collecting real-world data in different weather conditions and geographic locations.

A. Data

The images were obtained by continuous photographing with cameras installed on carriages - flaw detectors of long-distance and short-distance trains. As the carriages - flaw detectors moved, cameras took pictures of the near-track space on the right side, since the objects of interest to us (railway traffic lights) are to the right of the train at a distance of one meter.

The data were obtained in the amount of 59930 images of the near-path space with a resolution of 1920 x 1080 and a color rendering system RGB.

B. Preprocessing

The subject of our interest in the images are small and large railway traffic lights. Among the obtained images were selected those on which objects of interest to us are visible and distinguishable. Thus, 500 images were selected for marking.

To train a neural network, two sets of images are required as initial data. In this regard, 500 images were divided into two samples: train and test. Since the number of selected images is not large enough, the proportion of 90% for the training sample and 10% for the test sample was chosen so as not to lose valuable observations.

C. Neural network training

This section describes the neural network training technique used for detecting large and small railway traffic lights. The training was performed using the TensorFlow library [10] in a Jupyter laptop at Google Colaboratory (Colab) [11].

Preparing to train a neural network: Our learning process uses transfer learning [12], which is the application of a pretrained model to train on new data. That is, it is an optimization that allows you to quickly improve performance and progress when learning a new task. Thus, this process takes less time and is more likely to produce better results.

This study uses a faster_rcnn_inception_v2_coco model pretrained on a large and varied COCO dataset. When loading this model, the last checkpoint that was previously trained in the COCO dataset is retrieved [13]. Training a new model begins by using the reference point obtained as the starting point for training.

Training: After preparing all the necessary files, the process training started. It lasted 6 hours using a GPU accelerator. Below in Fig. 2 is presented a graph of the loss function, which shows how accurately the neural network finds the object in the image. The graph shows the number of thousands of steps horizontally, and the classification error value vertically.

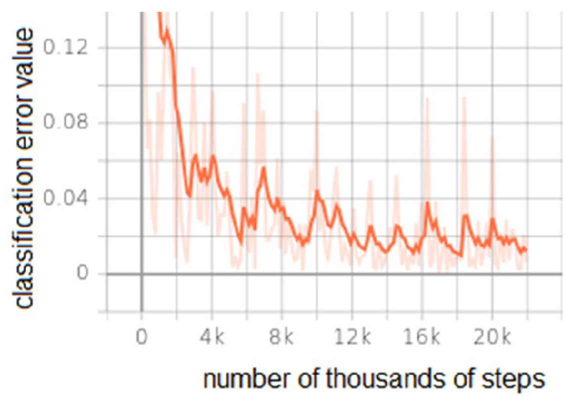

Fig. 2. Classification loss function

Each step of the training communicates a loss. During training, checkpoints are periodically saved, approximately every five minutes. The checkpoint with the highest number of steps will be used to generate the output graph.

IV. Computer Simulation Results

In this section, we will check the accuracy of the results obtained by the trained neural network on images that were not involved in the training process.

In the Table I are presented the errors of the first and second type after the work of the trained neural network. Errors of the second type are of interest, since the task of the next study will be recognition of markings at railway traffic lights. However, the shooting is carried out continuously, therefore, the presence of a small number of errors of the second kind is not critical: in one of the images [14], during the visibility time, the traffic light will be recognized.

Table 1. Errors of the first and second type for traffic lights detecting

	Type I error	Type II error
Small railway traffic lights	20%	2.5%
Large railway traffic lights	12%	1.3%

The Fig. 3 and Fig. 4 show that the large and small traffic lights are correctly identified with 99% and 99% accuracy, respectively.

Fig. 3. An example of detecting a large railway traffic light

Fig. 4. An example of detecting a small railway traffic light

In the following Fig. 5 it can be seen that a railway traffic light is detected even in poor visibility conditions: snow, rain or fog, with an accuracy of 98%, which means that the trained model is able to determine the objects of interest to us in images taken under different weather conditions.

Fig. 5. Photo taken in rain and fog

We also calculated the quality metric indicator — accuracy. Its value is equal to 87%, from which we can conclude that the model quite accurately determines the specified objects in the image and it has not achieved overfitting.

V. Railway Traffic Lights Information System

Currently, information about railway traffic lights is stored not only in electronic form, but also in the form of paper documents. This greatly complicates the search for the technical characteristics of a particular traffic light. In addition, the information may not be up to date. This requires the development of a specialized information system for storing and processing traffic light data.

The primary information about the traffic light in the form of a photo image is sent from the camera to the video server. Traffic light images are loaded from the video server according to the schedule to the data center for further processing in order to detect traffic lights and mark them. The processed image and marking data are loaded into the database of the information system for further use.

The core of the system is a complex of image processing programs, which implements an algorithm for detecting large and small railway traffic lights based on a convolutional neural network, as well as an algorithm for recognizing the text of the marking on them [15]. The information system diagram is shown in Fig.6.

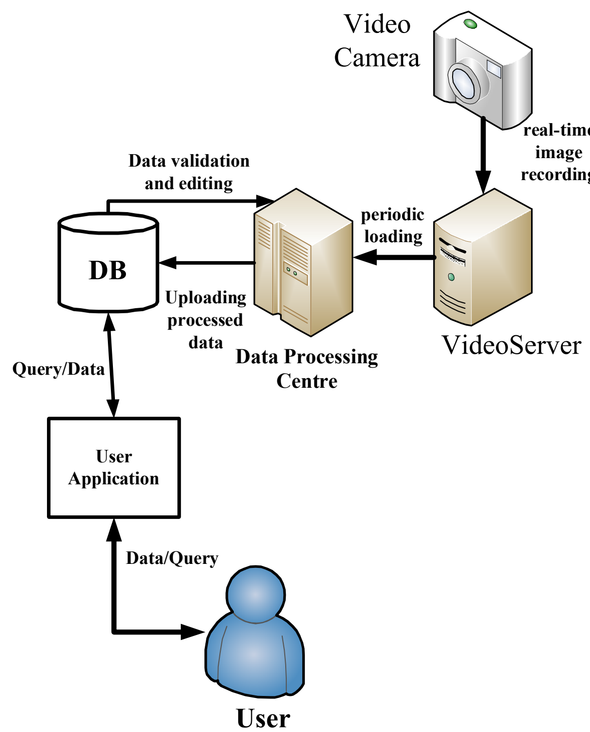

Fig. 6. The information system for railway traffic recognition recognition

The database stores images of traffic lights, as well as contextual information about railway traffic lightsThe central object in the database is the railway traffic light. The attributes of this object are presented in Table. 2.

Table 2. Railway traffic light information structure

Attribute Name	Description

ID	unique identification number, consisting of marking and traffic light position in km
Marking Plate	traffic light number
Traffic light type	small / large
Bbox size	size of the frame framing the object when it is detected
Bbox position	coordinates of the lower left corner of the frame framing the object
Marking	variable of bool type
Date and time of recording	the date and time of recording the attributes in the table
Position	the position of the traffic light in km corresponding to this track

The information system is implemented using a DBMS MySQL and development tools MS Visual Studio.

VI. Conclusion and Future Works

This paper proposes a new solution to solve the problem of recognizing traffic lights on railways. A neural network has been developed and trained to predict the traffic lights size and their marking. Also, a system was proposed to record, store, process and analyze data about detected objects.

In the future, it is planned to continue this research: to develop and implement an application that will recognize not only small and large railway traffic lights, but also other types, determine the location of railway traffic lights, the color of their signal and detect the fault in the traffic lights. It will be necessary to check the possibility of using other architectures of neural networks to improve the detection accuracy and reduce the computational complexity of algorithms.

References

[1] Sozykin A.V. “An Overview of Methods for Deep Learning in Neural Networks”. Bulletin of the South Ural State University. Series: Computational Mathematics and Software Engineering. 2017, vol. 6, no. 3, pp. 28–59. (in Russian).

[2] Torfi, A., Shirvani, R.A., Keneshloo, Y., Tavvaf, N., & Fox, E. “Natural Language Processing Advancements By Deep Learning: A Survey ”, 2020. ArXiv, abs/2003.01200.

[3] Gomez F.J., Schmidhuber J. “Co-Evolving Recurrent Neurons Learn Deep Memory POMDPs”. Proc. of the 2005 Conference on Genetic and Evolutionary Computation (GECCO) (Washington, DC, USA, June 25–29, 2005), 2005. pp. 491–498.

[4] Andres E. Gomez et al. “Traffic lights detection and state estimation using Hidden Markov Models”, 2014 IEEE Intelligent Vehicles Symposium Proceedings, p. 750-755, 2014.

[5] C. Wang, T. Jin, M. Yang, B. Wang. “Robust and Real-Time Traffic Lights Recognition in Complex Urban Environments. International Journal of Computational Intelligence Systems”, Vol. 4, No. 6, Dec 2011, pp. 1383-1390.

[6] Hyun-Koo Kim, Ju H. Park, Ho-Youl Jung. “Effective Traffic Lights Recognition Method for Real Time Driving Assistance System in the Daytime”, World Academy of Science, Engineering and Technology International Journal of Electrical and Computer Engineering. 2011, vol. 5, no. 11, pp. 1429-1432.

[7] Hobum Park, Nari Kim, Hahn Hernsoo, Youngjoon Han. “Traffic light detection and recognition using Adaboost classifier based on Haar-like features”. Proceedings of ISER 59 th International Conference, Prague, Czech Republic, 2017.

[8] Bin Qasim Ahmad, Pettirsch Arnd. “Recurrent Neural Networks for video object detection”. 2020. last revised 29 Oct 2020 (this version, v1) arXiv:2010.15740v1

[9] Rules of technical operation of railways: 3. Traffic lights.”, Moscow, 2020.

[10] Abadi M., Agarwal A. Barham P. “TensorFlow: Large-Scale Machine Learning on Heterogeneous Distributed Systems”. Proceedings of the 12th USENIX Symposium on Operating Systems Design and Implementation (OSDI ’16) (Savannah, GA, USA, November, 2–4, 2016), 2016, pp. 265–283.

[11] S. Haykin, “Neural Networks: A Comprehensive Foundation”, 2nd ed., Ontario: McMaster University, 1999, p. 50.

[12] Weiss K., Khoshgoftaar T.M., Wang D. “A Survey of Transfer Learning”. Journal of Big Data. 2016, vol. 3, no. 1. pp. 1–9

[13] J. Huang, V. Rathod, C. Sun, M. Zhu, A. Korattikara, A. Fathi, I. Fischer, Z. Wojna, Y. Song, S. Guadarrama, K. Murphy. “Speed/accuracy trade-offs for modern convolutional object detectors”, 2017, arXiv.org, 1611.10012

[14] V. John, K. Yoneda, B. Qi , Z. Liu , S. Mita. “Traffic light recognition in varying illumination using deep learning and saliency map”. Proceedings of 17th International IEEE Conference on Intelligent Transportation Systems (ITSC), 2014

[15] Nexar. traffic light detection contest. White paper, 2020

[16] Shruti Mittal, D. R. “Vision Based Railway Track Monitoring using Deep Learning”, 2018, arXiv.org, last revised 25 Nov 2018 (this version, v2)