A Study of the Impact of the Transport Queue Structure on the Traffic Capacity of a Signalized Intersection Using Neural Networks

Ibryaeva O. L., Shepelev V. D.,* Kuzmicheva O. D., Almetova Z. V., Zhulev A. E., Cherpakov A. O.

*South Ural State University (national research university), Chelyabinsk, 454080, Russia

Kazan Federal University, Kazan, 420008, Russia

Abstract

The article deals with the development of a computer system, which allows us to recognize vehicles, track them, and measure the time needed to cross an intersection by each car in the lane. The main area of research is the analysis of the dependence of the intersection crossing time on the position of vehicles in the queue formed in the traffic lane. To count the vehicles in the queue and determine their category, we used the Yolo v3 neural network and the SORT tracker modified to return the object class. All vehicles are divided into three categories depending on their acceleration. We analyzed the collected data on the queue structure and the time of its unloading and demonstrated their direct interconnection.

Keywords: traffic count; intersection; motor vehicles; vehicle queue; computer vision.

1. Introduction

Currently, V2V and V2I road traffic and computer vision systems have been actively developed, which allows us to solve problems in the road industry in a more efficient way – through the introduction of an intelligent transport system (ITS) (Lourenco et al. (2019), Husain et al. (2020)). This system uses innovative developments in transport system modeling and traffic flow regulation and provides end-users with informative and accurate data, which can help to qualitatively increase the interaction level of traffic participants. One of the most important criteria for the traffic flow monitoring and regulation is an analysis of the queue of vehicles at the intersection waiting to pass.

There is a very limited number of works studying the mutual influence of various categories of transport in the queue on the traffic capacity of signalized intersections (Dai et al. (2016), Dey et al. (2013), Li et al. (2016), Parmar et al. (2020), Mondal and Gupta (2019), Lomakin et al. (2018)).

This paper proposes a new practical approach to analyzing the dependence of the intersection crossing time on the position of transport category in the queue formed in the traffic lane. The purpose of the paper is to develop a computer system, which allows us to recognize a vehicle, track it and measure the time needed to cross an intersection by each car in the lane.

2. Materials and Methods

Yolo network training is a non-trivial task in itself. To this end, we used a repository (https://github.com/AlexeyAB/darknet) and 10,000 images with a size of 1920x1080 pixels annotated by 12 classes.
The training algorithm compresses the image to 960x480 pixels. The neural network operates using the Darknet technology.

Before tracking an object, you should detect it. We use detection to know about the appearance of an object, and then we monitor its position in the next frames using a tracker. To detect the same object on different frames, taking into account the change in its location, SORT uses mathematical heuristics, such as maximizing the IOU (intersection-over-union) metrics between rectangles surrounding objects in neighboring frames. Each rectangle is marked with a number (object id), and if there is no corresponding rectangle in the next frame, the algorithm assumes that the object has left this frame. It is natural that SORT accuracy largely depends on the quality of object detection.

3. Results and Discussion

Using the proposed algorithm, we collected the queue data at one of the central intersections in Chelyabinsk, Russia. Despite the fact that a trained neural network is able to classify objects into 12 classes, all vehicles were divided into 3 categories N1, N2, N3 depending on their acceleration. We selected one of sixteen queues for the analysis (which corresponds to straight traffic) and recorded the data obtained on 1000 allowed traffic signals. We selected ten types of queues of these objects (1 - all objects of class N1, 2 - the first object in the queue of class N2, the remaining objects of class N1, 3 - the second object of the queue of class N2, the remaining objects of N1, etc.). The presence of objects of class N2 with a low acceleration increases the time needed to cross the intersection, and these objects have the maximum impact if they are at the beginning of the queue, while the presence of such an object at the end of the queue (type 6) almost does not aggravate the situation. The movement of an object of class N2 from the beginning of the queue to its end will lead to an increase in the traffic capacity of the lane (directly) by 17%. We examined all the queues of seven objects with one object of type N2 and the remaining objects of type N1. When the object N2 moves to a place with position 5, 6 or 7 in this queue, the time of passing the queue can be reduced to 20%.

4. Summary

These studies were carried out for one particular intersection and only for the straight lane. Notably, the indicators of the vehicle acceleration, average speed, and traffic intensity are different for each lane, which will lead to a different analytical dependence. However, the proposed methodology is easily transferred to the cases of other lanes and intersections.

Thus, regulation of the intersection crossing procedure can significantly improve the traffic capacity and is a considerable reserve in the tasks of improving the efficiency of the road transport infrastructure.

References


