Smart Traffic Management System for the Krasnoyarsk City*

Roman Morozov[1], Margarita Favorskaya[2], Ivan Perevalov[3] and Tatiana Vitova[1]

[1] Institute of computational modelling of the Siberian Branch of the Russian Academy of Sciences, 50/44 Akademgorodok, Krasnoyarsk, 660036, Russia
[2] Reshetnev Siberian State University of Science and Technology, 31 Krasnoyarsky Rabochy pr., 660037, Krasnoyarsk, Russia
[3] Limited Liability Company "Modular Control Systems", 35A Partisan Zheleznyak st., Krasnoyarsk, 660022, Russia
frozzen@icm.krasn.ru

Abstract. The article describes the traffic management system being created in the city of Krasnoyarsk. The system is based on the developed new traffic detectors, which allow real-time determination of the parameters of traffic flows on the city streets. Computer vision algorithms are used to determine the traffic parameters. The traffic light objects are controlled, depending on the current traffic state.

Keywords: Traffic Management, Information System, Computer Vision.

1 Introduction

1.1 Traffic Management Relevance

Traffic jams in megacities have become a common everyday problem. Their duration and number are increasing every year. The transport costs are growing, the level of road safety is declining, and the environmental situation is deteriorating. Preventing or reducing the congestion of the transport network is only possible with the use of modern traffic management methods. Several methods are used to improve the efficiency of using the road network. They include traffic restrictions on certain road sections, entry restrictions to parts of the city, the introduction of tolls, the creation of paid parking space, and increased fines for violating traffic rules for stopping and parking. This also includes an increase in the prestige and comfort of using public transport. These measures are effective, which is confirmed by the world practice.

Expansion of the existing roads, construction of back-ups, interchanges, flyovers, bridges, tunnels, bypass roads allows the redistribution of traffic flows. This leads to the social and economic development of the city. The disadvantages of these measures are also obvious. The construction is very expensive and very timeconsuming, which can affect the calculated planned traffic improvement effect. Also, in many cases, major construction work is impossible.

The introduction of Automated Traffic Management Systems allows for the coordination of traffic, provides an adaptive regulation of traffic flows, a centralized collection of data on the characteristics of traffic flows, and centralized control of the vehicle traffic. The use of automated traffic control systems is a technological way to increase the efficiency of using the road network. The basic functionality of such systems is video surveillance of the traffic situation, centralized control of traffic light objects, automatic monitoring of traffic flow parameters, and automatic monitoring of the state of peripheral objects of the system. The advantages of this method are the achievement of a quick effect, the maintenance of high efficiency for a long time, and a significantly lower volume of costs, compared to major construction.

To manage the traffic flow, it is necessary to understand its characteristics; therefore, the key function of the system is to monitor the traffic flow parameters. The data sources can include the data from regular field surveys, specialized vehicle detectors, tracking data of vehicles from adjacent systems, and transport mathematical models. For example, a photo and video recording system can act as a data supplier according to the parameters of the traffic flows. Understanding and calculating the indicators such as the average speed on a road section, intensity, traffic density, vehicle types, road capacity, average vehicle delay in motion, time index, traffic service level, road congestion for a road section, buffer index, average queue length and its change over time gives us the basis for managing and responding to changes in the traffic flows. Visual observation of the traffic situation is provided by specialized traffic cameras capable of operating in difficult climatic conditions, resistant to pollution, and equipped with a swivel mechanism and a cleaning system.

1.2 Overview of Traffic Management Systems

A lot of traffic control systems have been developed. A number of them can be distinguished as strongest.

VISSIM is a simulation tool for designing traffic control systems. As a universal road traffic modelling system, VISSIM simulates links, nodes and minor road networks with a high level of detail. The modelling system consists of two programs. The first program solves the traffic simulation problem, the second - simulates the management of signals at traffic lights. VISSIM is a master program that sends per-second values of transport detectors in the program to control traffic signals. Management of traffic lights is based on the values of transport detectors to determine the current intervals of signals. The simulation is microscopic (single vehicle simulation) and stochastic with fixed time intervals. The simulation results give in a real-time transport flow animation, travel time and waiting time distribution reports [1].

The Intelligent Transport System (ITS) [2] worth $423 million has been designed to improve traffic management on Hong Kong's traffic network, which is one of the busiest road networks in the world. The project was launched in 2001 and completed in 2010. The main platforms, included in ITS to address traffic congestion, provide traffic management, monitoring, data analysis and control. This project has ensured the optimal traffic management by tracking all major highways, roads and road tunnels [3].

The development of the Adaptive Traffic Signal Management System for Wolf Road, NY [4] began in 2012. The goal of this project is to demonstrate Siemens ACS-Lite technology and an efficient signalling system at intersections along Wolf Road. The project team includes a member of Rensselaer Polytechnic Institute and City College of New York as well as Siemens ITS, SenSys Networks, and Annese and Associates. The project was successfully finished in 2013 [3].

Many other traffic management projects have been implemented [5-11]. Most systems are not universal and they are boxed products. They are adapted to the conditions of the particular metropolis and used within the general management system. The boxed products have a high cost and usually require expensive equipment.

2 Smart Traffic Management System

The developed system allows for the optimum traffic light regulation at the intersection of traffic flows in order to reduce the likelihood of road accidents taking into account the current situation.

The main goals of the system are:

- collection of data on traffic flows at the approaches to the intersection for adaptive control of the traffic light object;
- implementation of traffic light regulation of traffic flows in regular and abnormal modes;
- improving the safety of the functioning of public transport;
- analysis of the vehicle traffic, volumes, and intensity of vehicles;
- presentation of data on the vehicle traffic and indicators for all the interested users using the web interface.

A set of technical means of a traffic light control system is a set of peripheral devices (traffic lights, road controllers, communication equipment, etc.) and a central complex of technical means (server equipment, data storage equipment, data network equipment).

All the peripheral devices are physically connected using a data transmission system. To provide the data transmission from the peripheral equipment of the system to the central module located in the data center, a virtual private network was created using wired and fiber-optic networks, as well as wireless communication channels, which provides sufficient speed and bandwidth for connecting external data sources.

Integration of the existing traffic light objects is provided by their modernization in terms of replacing the outdated equipment and retrofitting it with transport detectors to implement local and coordinated control. The integration is performed employing the data exchange protocols used in the equipment. Connecting traffic light objects to the Intelligent Traffic Light Control System can be performed in two ways. Their choice depends on the availability of wireless links and public channels (Internet). When using public communication channels, the information must be encrypted.

A vehicle detector has been created which collects information on the state of the road network. The vehicle detector is named Optic-T1. The technical characteristics of the detector are approved, the detector itself is certified. The vehicle detector is a high-resolution night vision camera that collects video information on a section of the road network; then the information is processed using a pattern recognition system. The image recognition is performed using a Raspberry Pi 3 microcomputer. The image processing system is based on the Open Source Computer Vision Library (OpenCV) with a significant refinement taking into account the peculiarity of the system, time, camera location, weather conditions, and other factors. OpenCV is an open-source library of general-purpose computer vision, image processing, and numerical algorithms. Being implemented in C / C ++, it is also developed for Python, Java, Ruby, Matlab, Lua, and other languages. It is free to use for academic and commercial purposes and is distributed under the BSD license. In order to speed up image processing, the Intel Performance Libraries and Intel Math Kernel Library are used.

The smart traffic management system includes specific modules distinguishing it from other similar ones:

- a tracking module has been introduced, which collects data on the movement of an escorted vehicle along the route entered by a traffic engineer, based on the GLONASS terminal installed on the escorted vehicle, which automatically recalculates signal plans, coordination plans and sends them through the server to controllers for coordinated control of traffic light objects, ensuring unimpeded movement along the route of the accompanied vehicle and optimizing traffic flows on the sections of the road network adjacent to the route, unloading the resulting congestion after the passage of each traffic light by the accompanied vehicle;
- the module "information panel" has been introduced which allows one to quickly display the initial data on the user's preference, visualize traffic flows, control the movement of priority vehicles (municipal service vehicles, public transport, Ministry of Emergencies, traffic police, ambulance);
- a modeling and analytics module has been introduced which creates and edits city graphs modeling engineering solutions related to planning repairs, expanding and reconstructing roads, relocating stops, organizing parking space, analyzing traffic flow data and optimizing coordination plans for managing traffic light objects, and providing movement along with the "green wave".

3 Conclusion

The newly developed vehicle detector is installed at the intersections of the city of Krasnoyarsk and it is used to collect statistics on the traffic. An intelligent traffic management system has been developed and is being tested in Krasnoyarsk. A telematics system has also been developed which complements the traffic management system and will be tested in the second half of 2020. The task of the main and district traffic control is to consider traffic congestion around the controlled intersection.

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