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Traffic Lights Management Using Optimization Tool

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Abstract

The increase of traffic is one of today's problems. Numerous cities are affected by traffic congestion and the increase of emissions from fuel use. They have a negative impact on economy, environment and overall on the quality of life. It is necessary to find intelligent solutions for road traffic management. The interest for intelligent traffic systems appeared at the beginning of the 20th century. There are various methods available for traffic management such as inductive loop detection, infrared sensors, video data analysis etc. The purpose of this paper is to present an approach of optimization tool using in order to decrease the traffic congestion and the crossing time of a road network.

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Keywords: intelligent transportation systems; optimization; traffic lights

1. Introduction

"Intelligent Transportation Systems, or ITS, can be defined as the application of computing, information, and communications technologies to the real-time management of vehicles and networks involving the movement of people, goods, and services " (Samadi, S., Rad, A.P., Kazemi, F.M., & Jafarian, H., 2012).

In order to understand the transportation system and the need to model traffic flow, we must first understand the causes of mobility and how it is achieved. People's daily activities generate the need for people and goods to move between different locations. "The transportation system provides the infrastructures and means, ensuring that both persons and freight will be at the right location at the right time to perform the activities that will result in products and services when they are required by the market " (Barceló, J., 2010).

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2. Traffic modeling and simulation

Traffic dynamics can be defined by mathematical traffic flows obtained through the interaction between drivers, vehicles and infrastructure. Thus, in these mathematical models, large amounts of information are taken into account: the behavior of drivers in terms of the degree of acceleration of the car, the agglomeration of the streets, the speed at which they travel, the pedestrian flow, the positioning of the road signs, etc. By processing these data, it is desirable to get the best possible time to cross the intersections, in order to reduce road jams.

Based on the data obtained from various traffic monitoring sensor networks, simulation models are developed. By running a simulation model, predictions of traffic evolution can be made and intersections with the highest risk of blockage can be seen.

It is noteworthy that the values for the model parameters are chosen so that the simulation will match the data obtained from the traffic. This operation is called the model's calibration, and its endpoint consists of a calibrated model that can be used to predict traffic flow. A schematic representation of all these considerations is presented in Fig. 1.

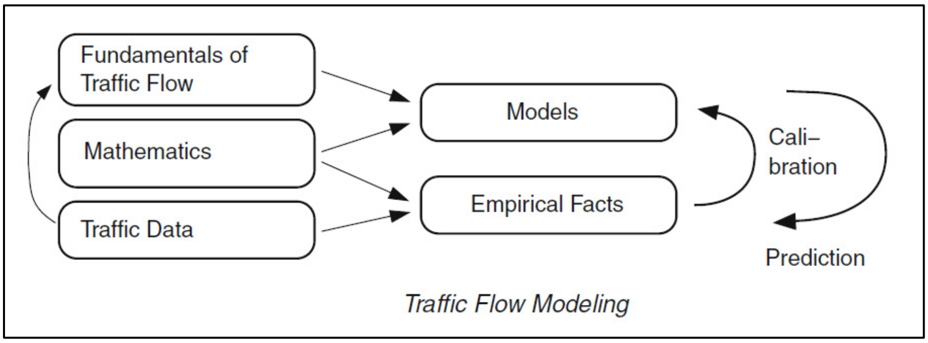

Fig. 1. Traffic Flow Modeling (Treiber, M., & Kesting, A., 2013)

A clearer relationship between simulated and real-time traffic systems is represented in Fig. 2. In order to validate a simulated traffic system, it should reproduce in a realistic manner the real system. The simulated system receives as inputs the values from the real system. Besides, there are also entries that cannot be directly observed, requiring the use of estimated values. From the category of inputs to be estimated we can specify the dynamics of origin-destination matrices.

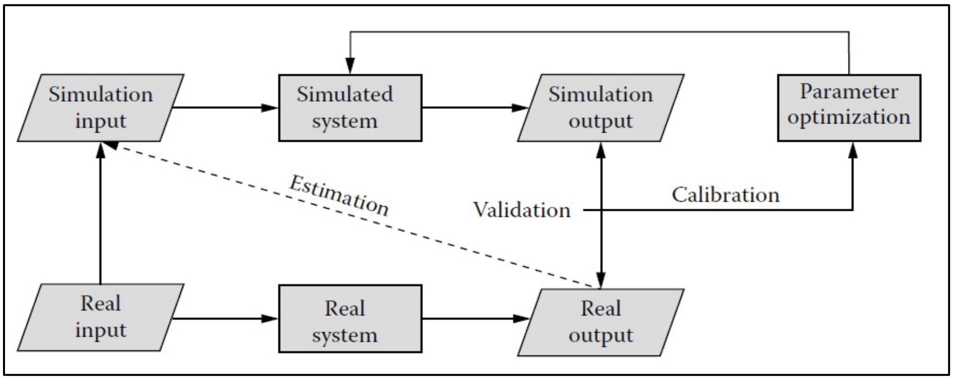

Fig. 2. Relationship of simulated and real systems and locations of calibration and validation processes (Daamen, W., Buisson, C., & Hoogendoorn, S.P., 2015)

It can be noticed that in the proposed architecture, in the calibration, the simulation output values are compared with the data corresponding to the real system. Following this comparison, an adjustment of the simulated system parameters will be made so that the differences between the two outputs are minimal or reach a minimum specified by the requirements.

3. Related work

Within traffic systems, it is desirable to obtain optimal solutions for the fluidization of traffic. The trend is to develop the most efficient algorithms of adaptive traffic control using concepts such as parameter estimation, fuzzy logic, or artificial intelligence.

An innovative approach in traffic lights management is to take in account also the pedestrians. “Genetic algorithm is introduced in the traffic control system to provide an intelligent green interval response based on dynamic traffic load inputs, thereby overcoming the inefficiencies of conventional traffic controllers. In this way, the challenges are resolved as the number of vehicles are read from sensors put at every lane in a four-way, two-lane junction and pedestrians are monitored at the road junction” (Turky, A.M., Ahmad, M.S., & Yusoff, M.Z.M., 2009). This approach seems to be the first that apply genetic algorithm on pedestrians crossings. Chromosome selection is made via roulette wheel selection. The fitness function obtained is used to decide the green and red times for traffic lights. Also, is taken in account the chromosome recombination until the maximum number of generations is reached.

Another approach is based on potential vehicle queue spillover detection, measuring only the vehicle speed without taking in account the queue length. After the vehicle speed was obtained, “three traffic light switching triggers were defined according to the detection of queue spillover. These triggers play as indicators of the time of changing traffic light from green to red (ECG) or from red to green (RUG) when the downstream congestion is mitigated. Finally, a decision tree based adaptive signal control scheme was developed based on these signal switching triggers and other constraints” (Ren, Y., Wang, Y., Yu, G., Liu, H., & Xiao, L., 2017).

The traffic lights can be controlled using a method based on parameter estimation. One of the simplest approaches is to use the microscopic representation of traffic. This type of model is characterized by the emphasis on studying the individual behavior of each vehicle on the road network or on the length of the queues in a discrete time system. Microscopic models contain four levels of representation for the road network load model:

- intersections configuration;
- links;
- lane choice;
- vehicle-following.

Based on this microscopic representation, an online adaptive traffic signal control algorithm is developed and the behavior of traffic lights is studied. The system is modeled by using a state called traffic status. The current number of vehicles that form a queue at the level of a lane is represented by a vector. Also, a vector corresponding to the traffic lights signals is defined. Action is the decision the system takes at a time t and is denoted in vectorial form. For each moving lane, it is possible to decide whether the color of the traffic light signal should be maintained or changed based on action vector values. “The network loading model and traffic signal control model are generally constructed in discrete-time, as much as possible to the real circumstance. By comparing different methods, results show that approximate dynamic programming (ADP) with adaptive phase sequence (APS) mode has a quite good performance of queue length and traffic delay reductions” (Yin, B., Dridi, M., & El Moudni, A., 2015). Can be noticed that this approach has a good potential for autonomous intersection management.

In 2012-2013, the implementation of the pilot safety model for vehicles connected using wireless communication networks takes place in Ann Arbor, Michigan. Testing concluded that Vehicle-to-Vehicle (V2V) technology could significantly reduce the number of accidents through safety applications that can warn drivers of possible collisions with other vehicles or even automate braking to avoid accidents. This method was applied on a single traffic intersection, with eigth possible directions for vehicle movement. Was developed a Greedy forwarding algorithm that succeeds to reduced the delays experienced by the vehicles when are tryin to cross a road network. For collecting necessary data was used a sensor network. “The broadcast medium is the 5.9–5.95-GHz radio spectrum, and the communication standards are defined in the IEEE 802.11p standards. The information consists of speed and position data collected from vehicles. Speed data can be gathered from the vehicle speedometers, and position data can be gathered using GPS receivers fitted to the vehicles. In our implementation, the following data are gathered and encapsulated in data packets that are broadcast over the wireless medium” (Yugapriya, R., Dhivya, P., Dhivya, M.M., & Kirubakaran, S., 2014).

4. Study methodology and simulation

4.1. Agent-Based Modeling

Agent-Based Modeling (ABM) can be regarded as a modeling style in which individuals and how they interact, as well as their environment, are explicitly represented in a program or even in another physical entity.

This type of modeling is associated with the object-oriented programming style. In object-oriented programming languages, such as Java, data and programming methods or procedures are encapsulated in objects that can operate their own data and interact with other objects. One of the features of object-oriented programming language that manages agent-based modeling is inheritance. Thus, it can be noted that ABM has a programming style associated, which is suitable for representing individuals or different objects as agents in a program.

In agent-based modeling, account must be taken of:

- control over the simulation features such as the structure of the environment or the initial positioning of the agents;
- ways of collecting and analyzing data obtained from simulation;
- the possibility of obtaining insufficient information to issue objective conclusions from running a single experiment;
- the need to apply optimization algorithms in order to obtain improvements for the model system.

4.2. Traffic simulation of intersection "Electro"

For modeling and experimental simulation of the intersection "Electro", was used AnyLogic modeling tool. "AnyLogic is the unique simulation software tool that supports three simulation modeling methods: system dynamics, discrete event, and agent based modeling and allows you to create multi-method models"(Grigoryev, I., 2016).

Fig.3 shows an overview of traffic simulation at the intersection "Electro". The intersection is characterized by the fact that the traffic lights alternate at one moment only one of the green traffic lights. In this paper will be presented two modes of traffic lights configuration and how these configuration modes can influence the vehicle movement.

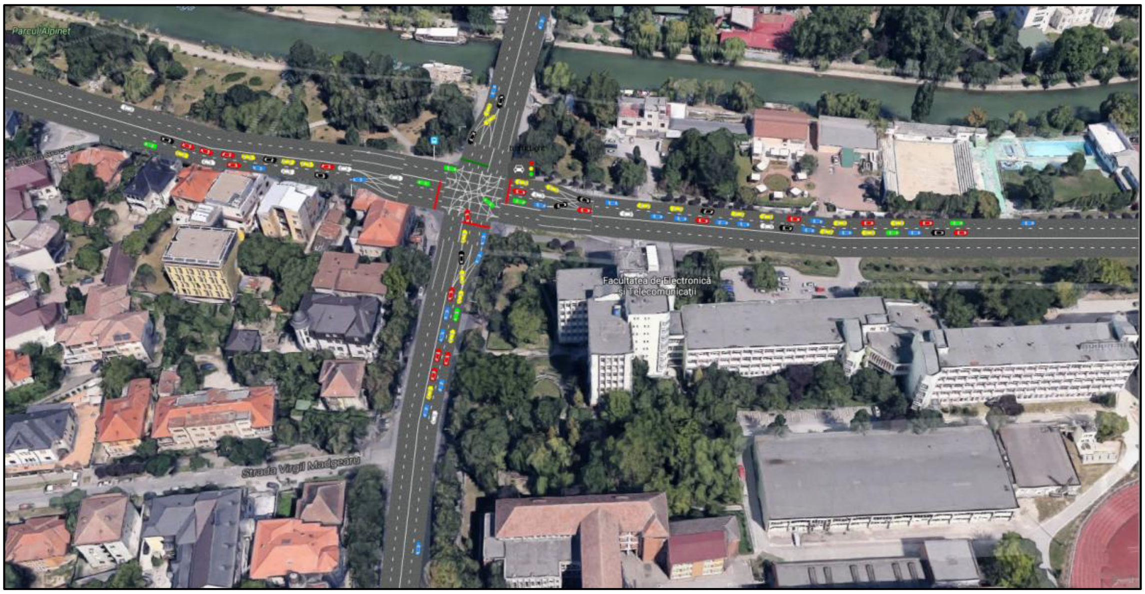

Fig. 3. Traffic simulation of intersection "Electro"

4.3. Traffic lights configuration

Traffic lights (Fig. 4) are alternately synchronized, taking into account the direction of movement of the cars. Directions that are given green at the same time are chosen in such a way as to avoid collisions between cars. In this way, cars coming from the Cathedral and moving towards the Passage Michelangelo and those coming from Mihai Viteazu with the direction of going to Tudor Vladimirescu Street will have green at the same time and will bypass the imaginary center of the intersection in order to follow the route .

Fig. 4. Traffic lights configuration based on intersection’s lane connectors

Another way to configure traffic lights is shown in Fig. 5. In this case, traffic lights are alternately synchronized and a traffic light has been considered to be green for 40 seconds. These times have been memorized in the duration parameters so that they can then be optimized. As a disadvantage of modeling in AnyLogic, we can mention that switching from the red color of the traffic light to the green one is only made by the previous shift to the amber color.

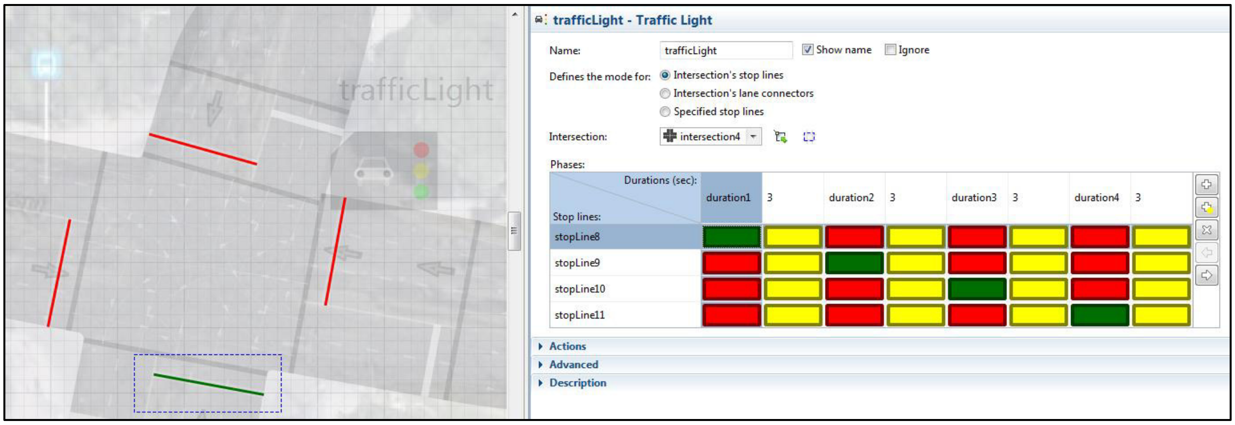

Fig. 5. Traffic lights configuration based on intersection’s stop lines

4.4. Optimization simulation experiment

In order to be able to see optimization possibilities for the times associated with traffic lights, an optimization simulation experiment was created. It has been chosen that each traffic light phase can take between 10 and 50 seconds in order to obtain a minimum average crossing time. This optimization simulation experiment was adapted to both cases of intersection’s traffic lights configuration. In both cases, the optimization experiment will be run for 500 iterations.

5. Results and analysis

The simulation's interest parameter is the mean time necessary for a car to cross the road network. In order to be able to see the evolution of this parameter, a specific block was added in the simulation. The data will be retrieved from each car, independent of its type, when the cars are leaving the road network.

In Fig. 6 we can see the best time obtained for crossing the road network, after running optimization experiment for 500 iterations. In this optimization experiment for each iteration the time for each traffic light phase is changed, the values used are between 10 to 50 seconds. After each iteration these values can increase or decrease with 2 seconds, but remaining in the specified interval. The optimized time for traffic lights, in both cases of intersection configuration, are listed in table 1. Also, in table 1 we can see the initial timming associated with traffic lights phases.

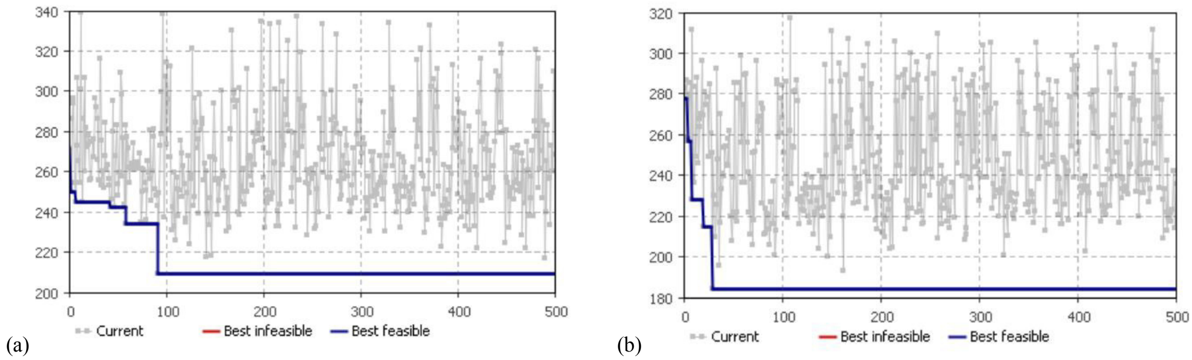

Fig. 6. Optimization simulation experiment for configuration based on: (a) intersection's lane connectors; (b) intersection's stop lines.

Table 1. Time associated with traffic lights phases.

Traffic light configuration mode	duration1 (s)	duration2 (s)	duration3 (s)	duration4 (s)
Intersection's lane connectors (initial time)	40	40	40	40
Intersection's lane connectors (optimized time)	46	50	12	10
Intersection's stop lines (initial time)	40	40	40	40
Intersection's stop lines (optimized time)	50	50	10	10

The mean time necessary to cross the road network is shown in table 2 and was obtained after running the simulation for 15 minutes and the travel speed was considered to be 50 km/h. The values from table shows a decrease with 15.10% of the mean time if we choose the configuration based on intersection's stop lines instead of configuration based on intersection's lane connectors. Using the optimized values for traffic lights phases we can see a decrease with 32.15 % of the mean time necessary to a car to cross the road network in the case of configuration based on intersection's lane connectors. Also, we can see a decrease with 31.22 % in the case of configuration based on intersection's stop lines. In the case of using optimized values for traffic lights phases the difference between the configuration modes is reduced to 11.92 % in behalf of the configuration based on intersection's stop lines.

Table 2. Mean time to cross the road network.

Traffic light configuration mode	Mean time before optimization (s)	Mean time after optimization (s)
Intersection's lane connectors	308.343	209.192
Intersection's stop lines	267.879	184.255

6. Conclusion

The continuous evolution of the economy and the growth of the population are increasing the mobility issue. It is hoped that the movement between two locations can be achieved as safely and quickly as possible.

Studies shown that by modeling real traffic situations, solutions for transport optimization can be found. Various traffic patterns have been developed on various levels of abstraction to give the information of interest as clear as possible.

Agent-based modeling is a modeling style that manages to capture individuals and how they interact. The application of this method has been done in this paper using the AnyLogic simulation tool. Through the library dedicated to road transport modeling, AnyLogic offers extensive study opportunities on traffic. The most relevant point of study within a network are intersections. Traffic mode configuration is decisive in traffic flow.

AnyLogic use was able to show how traffic can be optimized by modifying the times associated with traffic lights phases. Optimization solutions were obtained by running an optimization experiment.

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