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Implementation of a hybrid method for optimizing traffic light phases using Anylogic

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Abstract. Traffic light interval signals have been operating according to the same pattern for many years. Small towns do not create traffic control units due to high costs. The operation of a traffic light is limited to several modes or has constant values of the temporary duration of traffic light phases throughout the day, which makes it difficult to organize traffic during times of high traffic loads on the road network. An algorithm is proposed for optimizing the traffic light phases of traffic flows at a T-shaped intersection depending on the traffic load on the network, which changes during the day. The effectiveness of the proposed algorithm is demonstrated by numerical experiment.

1 Introduction

One of the key problems of modern cities is the constantly increasing traffic flows, which lead to increased load on public roads. Solving this issue through road reconstruction is complicated by high costs and the inability to transfer traffic flows to duplicate directions, so optimizing traffic light phases is an alternative solution to the issue of modernizing the road network. Traffic light settings should tend to green phases in different directions of movement with a constant maximum traffic flow at the exit and a minimum traffic flow in the red phase, in order to create a small car drive that will move apart at the new green traffic light phase [1]. Depending on the time of day and traffic situation, the priorities for crossing intersections for different directions should change, giving preference to the busiest direction, and minimum priority to the least congested. The frequency of traffic light phase updates is selected depending on the complexity of the intersection and the current traffic situation; it is preferable to adjust the traffic light phases as often as possible. The paper considers a model of a T-shaped intersection of the road network of the city of Krasnoyarsk. This intersection is characterized by the connection of three highways, which are controlled by one traffic light. Traffic light phase control settings are configured remotely by the operator, depending on the time of day [2]. Each road has four lanes, two in each direction. The traffic light controls roads 2,3 in one green phase and road 1 in the other. The movement from side 2 to side 1 is controlled by an additional section.

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2 Problem statement

The timing of traffic lights must be constantly adjusted. The load on the network will be different at different times of the day. In the mornings, motorists usually go to the city, and in the evenings from the city.

3 Research questions

Based on the described situation, the following questions were posed for solution:

- What algorithm can be used to adjust the phases of a traffic light?
- How often do you adjust traffic light phases?

4 Purpose of the study

To regulate the phases of traffic lights, a hybrid mathematical model is proposed, which is based on simulation modeling in the Anylogic software package [3,4] at the macroscopic level. The mathematical model is focused on various traffic flows, which are redistributed using a traffic light phase control algorithm [5]. For the experiment to be correct, it is necessary to collect statistics from the intersection under study (traffic light operation, the number of passing cars at different times of the day), and then develop a model.

5 Research methods

The proposed traffic light algorithm works with stochastic traffic flows and allows minimizing vehicle idle time when other directions have low load, and maximizing the overall throughput when it is necessary to use optimal traffic light phases to solve the problem of high congestion. The convenience of the algorithm lies in the fact that it is possible to enter into it the necessary parameters of traffic light phases that are suitable for the street intersection under study. The algorithm receives basic values about the traffic light phases, creates a general phase of the traffic light cycle, depending on the number of cars passing through stop lines, which are recorded by video recording services or other means of accumulating statistics, and collects information about the passing cars during the general cycle. The following describes the necessary conditions for reducing or increasing the overall cycle, as well as redistributing the duration of the green phases of the traffic light to organize traffic [6].

In block 4, the counters of cars that have passed through stop lines are reset. After passing the full algorithm, if it continues to work, then the phase parameters are set again. In block 5, the traffic light phase values for different directions are initiated. In block 6, the counter of cars driven per cycle is initiated. In block 7, the traffic light cycle is reset and a new one is set based on the results of the previous cycle. Next, before starting the algorithm again, the conditions are checked, how many cars have passed and, depending on the conditions, new traffic light phases are selected. In block 15, the initiation of a new cycle is checked; if it does not start, then the algorithm ends. Values 10 and 20 are indicated for example and are calculated in seconds; in reality, the operator himself will set or the system will initiate the necessary values for a specific intersection. The algorithm ends with block 16, it can go to another algorithm or the traffic light simply stops working and the algorithm ends. The following is the pseudocode of the algorithm.

Pseudocode:

<Operation 1><BEGIN>
<Operation 2><Set model>

```
<Operation 3><Control>
<Operation 4><INIT z=0; z1=0;>
<Operation 5><INIT Parameter=xi; Parameter1=yi;>
<Operation 6>< INCREMENT z=i+1; z1=i+1>
<Operation 7>< INCREMENT Ti=ti+1; i=i+1>
<Operation 8><COMPUTE Parameter; Parameter1;>
<Operation 9> IF < z>=20; z1>=10;>
THEN < Operation 15> <Ti<n+1>
ELSE < Operation 10> IF <z<=20; z1>=10;>
THEN < Operation 13> < INIT Parameter=x1; Parameter1=y1;>
ELSE < Operation 11> IF <z>=20; z1<=10;>
THEN < Operation 14> < INIT Parameter=x2; Parameter1=y2;>
ELSE< Operation 12> < INIT Parameter=x3; Parameter1=y3;>
< Operation 15> IF <Ti<n+1>
THEN < Operation 4> < INIT z=0; z1=0>
END IF < Operation 16> <END>
```

In a similar way, algorithms with an increased number of traffic light phases can be described. The algorithm allows you to reduce the waiting time for the green phase if there is no traffic flow from the other direction. Small errors in the operation of passing vehicle recognition systems will not greatly affect the operation of the algorithm.

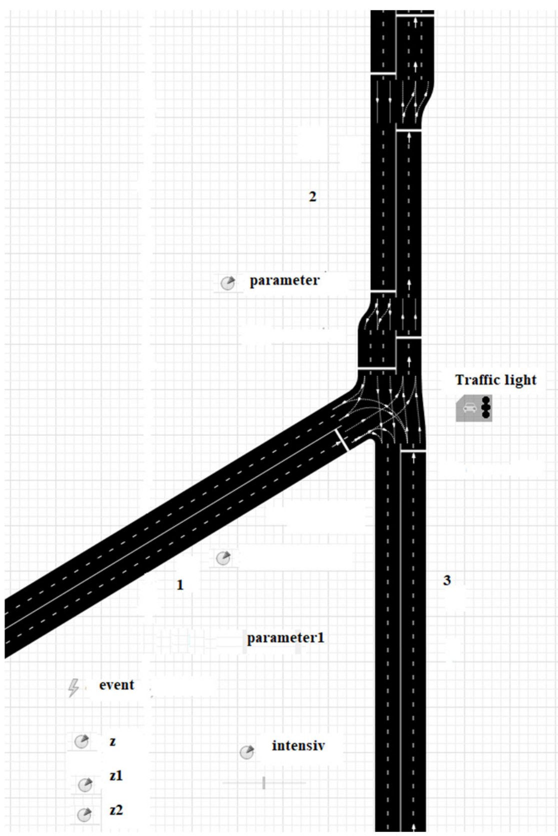

Fig. 1. Street intersection model.

Using the AVEDEX program or another development, you can read current data from CCTV cameras about the number of cars passing through the stop lines of the intersection. If the load on several roads is high, then the algorithm allows each complete traffic light cycle to change the phases of the traffic lights, adapting them for the most congested intersections. This will lead to a reduction in both overall and local average crossing times.

The maximum capacity of one lane while maintaining a safe distance is from 400 to 600 cars per hour, for two lanes - 800 cars per hour and 1200 cars for three lanes per hour under conditions of good weather, accident-free conditions and low traffic load. Signal waves should change during the day due to changes in traffic flows, i.e. choose the required algorithm or the required solution. The model of the intersection of road intersections, Svobodny-Lesoparkovaya streets is presented in Figure 1.

The z parameter counts the number of cars passing in directions 2 and 3; these roads are combined into one parameter, because they operate in one traffic light phase. Parameter z1 counts the number of cars passing in direction 1[7]. Depending on the values obtained per cycle, the traffic light phases change. These parameters are reset every traffic light cycle. The traffic light phases that are currently operating at this intersection and the number of cars that manage to pass at high loads during rush hour and at other non-load times are presented in Table 1.

Table 1. Current phases of the duration of the traffic light network at a given intersection and the number of passing cars.

Direction	Timings (sec)	Number of cars passing during rush hour on average per cycle	Timings (sec)	Number of passing cars during the unloaded period of time
1-2	55	15	35	13
1-3		24		8
2-1	110	28	90	28
2-3		25		21
3-1		20		13
3-2		18		19

The traffic light changes phases depending on the time of day when different traffic flows are expected, but does not adapt to rapidly changing situations, so capacity may be lost.

If the intersection is T-shaped, then there may be changes in two or three phases of the traffic light. Shorter traffic light phases accommodate a small number of vehicles from all directions so that overall throughput is increased and there is no downtime. If only one direction is characterized by a small flow of cars, then the time is redistributed to other directions; if a small number of cars are moving from two directions, then the duration of the phases in other directions increases. It is also recommended to reduce the night phases of traffic lights, since this can have a positive effect on the speed of movement from point A to point B and the condition of drivers, since the wait for a green signal is reduced to one minute or 40 seconds.

Using the OptQuest optimizer built into Anylogic, we will find the best traffic light phases for the overall maximum throughput with maximum values of traffic light phases. To do this, all cars that pass through the model are recorded in the variable z2, and the optimizer finds the maximum value of the variable [8,9], for different parameters of the traffic light phases.

The optimizer identified the phase parameters indicated in Table 2 at a load of 600 vehicles per hour from each direction.

Table 2. Optimized lengths of temporary network phases at an intersection.

Direction	Timings (sec)	Number of cars passing during rush hour on average per cycle
1-2	45	13
1-3		19
2-1	70	26
2-3		24
3-1		20
3-2		17

Shorter traffic light phases are more effective than longer ones, as this leads to a reduction in vehicle idle time at the traffic light.

6 Results and discussion

Consider the logic of the traffic light algorithm process in the proposed model. There are two parameters installed at the intersection, each of them collects stop line travel data. The "event" condition sets new traffic light phases, depending on the conditions met, and resets the parameter data every full cycle of traffic light phases. An "intensiv" parameter is attached to the intersection, which changes the flow of traffic while the model is running. This parameter can be attached to either one vehicle creation initiation or several. A slider is created that can adjust the flow increase with a certain minimum and maximum value increment. When the slider state changes after one cycle, the system reads the data and reconfigures the traffic light phases for the next traffic light cycle.

Consider the algorithm for adjusting the traffic light phases, which was introduced into the model. At low load (100 cars per hour), the traffic light changes phases to 40 (parameter) and 20 (parameter1) (lasts from 0 to 20 minutes). With a sharp increase to 600 cars per hour from 20 to 40 minutes with traffic light phases 70 and 45, with a sharp decline from 40 to 60 minutes to 100 cars, the traffic light changes phases to 40 (parameter) and 20 (parameter1) [10]. The results are presented as the average time a vehicle spends in the system from its appearance to its location. The results of the work are shown in Table 3.

Table 3. Results of models with different phases.

Direction	Average time spent by machines in the system at phases 55 and 110 (seconds)	Average time spent by machines in the system at phases 35 and 90 (seconds)	Average time spent by machines in the system at phases 70/45 and 40/20 (seconds)
1-2	422	449	313
1-3			
2-1	178	176	165
2-3			
3-1	53	58	50
3-2			

The average time cars spend in the system decreases when using the algorithm. It follows that the average travel time can be reduced if the traffic lights are constantly adjusted.

7 Conclusion

The proposed hybrid model makes it possible to adjust the traffic light phases depending on the road load. The model assumes a redistribution of time intervals to relieve congestion in the direction in which traffic flows increase, and increases the duration of the green phase, where necessary. The model algorithm increases the throughput of the intersection and reduces the time a car spends in the system, which is confirmed by the results of modeling various situations.

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