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SIMULATION OF CROSSROAD TRAFFIC

ABSTRACT

It is difficult to find the right tool for making traffic regime models because so many different situations are involved. SIMULINK has proved to be one of the best. The paper shows the design and the use of components and models in the program Matlab/SIMULINK. It presents the simulation results for the model of a traffic light controlled crossroadand indicates the possibilities for the study of traffic optimisation in junctions.

KEY WORDS

traffic, traffic light-controlled crossroads, simulation, optimisation

1. INTRODUCTION

The objective of this paper is to show how to develop and perform the simulation of any traffic problem in a relatively simple way with the use of standard simulation tools. With Matlab/SIMULINK we can build our own simulation blocks and adapt them to the particular needs of the problem we are resolving in cases when there is no adequate tool, or when the specific software (e.g. Netsim) is not available for any reason whatsoever. A rich library of standard blocks and fine user-friendliness make it possible for any user, even the one who has not been specifically trained to program and to use these tools, to learn quickly to use the methods for traffic simulation.

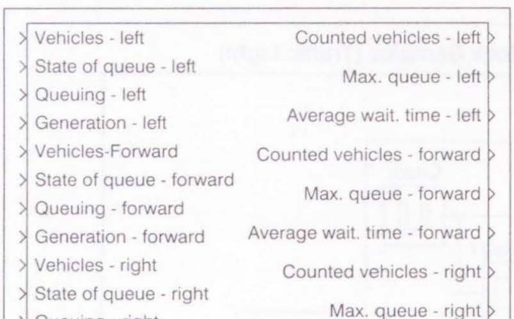

Figure 1 - Block symbol Statistika004

In addition, we will show how to optimise the time intervals of all phases of the control program for a real traffic light controlled crossroad with heavy traffic loading. Some of the blocks will be presented, built to make various models and simulate them. The characteristics of the system are predominantly stochastic, so the results will be stochastic, too.

2. THE DESCRIPTION OF BLOCKS

In order to facilitate the composition of crossroad or other traffic models we made a library of blocks. These blocks can be easily and quickly composed into a model, subsequently used to perform analyses. Only the most important blocks will be presented.

2.1 Statistika004

This block represents the joining of three blocks into one block called Statistika004 (Statistics). They have been joined to improve the clarity of the models we are designing. Each of the sub-units contains the data on one of the possible driving directions in any crossroad of an urban road-traffic system. The block is shown in Fig.1.

2.2 Semafor

The block Semafor (Traffic light) serves for the modelling and simulation of crossroads (at-grade junctions). In this case the option of direction-independent throughput of traffic light controlled crossroads is possible (Figure 2).

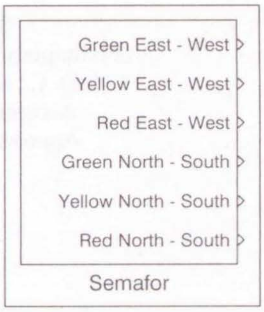

Figure 2 - Block symbol Semafor (Traffic light)

The open and closed time periods for individual directions are defined by three parameters. We only have to enter the green, red and yellow (amber) times for one direction. The intervals for lights in the opposite direction are generated automatically. The parameters entered interactively via the entry window are saved in the variables zep, rup and rdp.

The entered parameters are then used to determine the duration of signals for each light, and also the active and the break period within one time period. A discrete pulse generator was used as the signal supply source. All signals were denied. For individual lights they were adequately delayed. The delayed signals then run through the sign determination block, where every positive value is assigned the value 1, every negative value is assigned the value -1, while 0 remains 0. The memory block placed at the exit prevents errors in the operation of models. The sub-unit of block 1 is shown in Fig. 3.

2.3 The user block Generator Vozil 004 (Vehicle Generator 004)

The presented user block serves to generate vehicles on the basis of exponential distribution. It can be

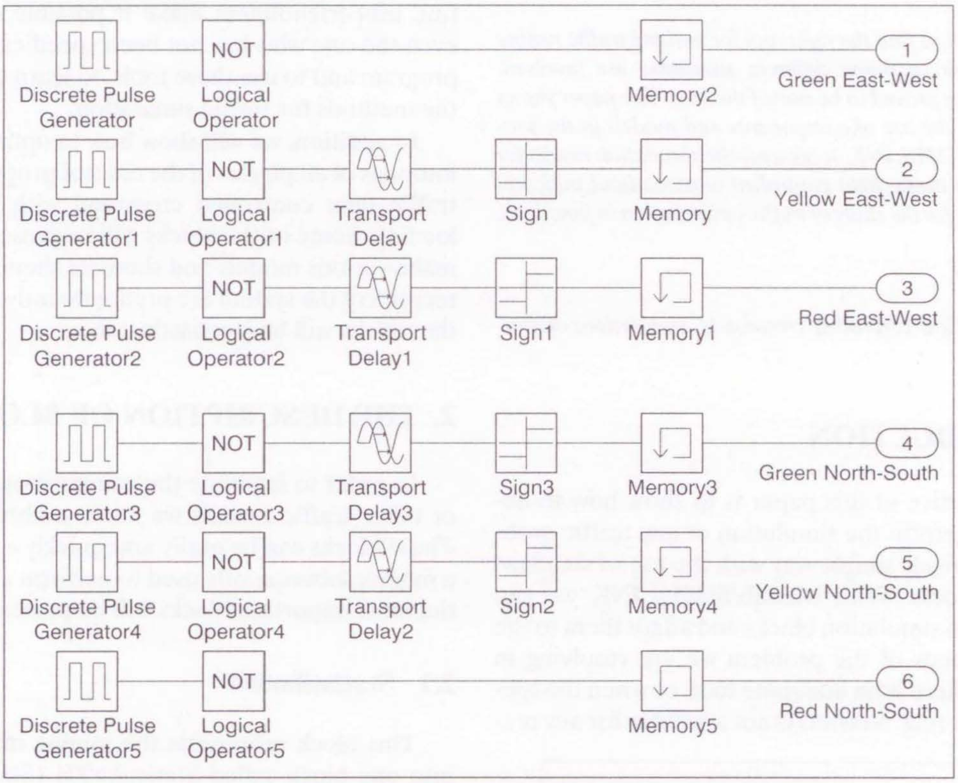

Figure 3 - The sub-unit of the block Semafor (Traffic Light)

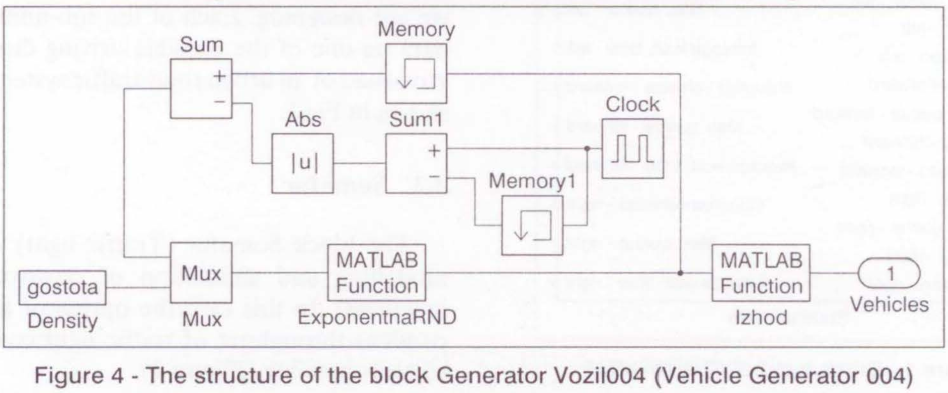

Figure 4 - The structure of the block Generator Vozil004 (Vehicle Generator 004)

used for crossroads and toll stations. The structure of the block Generator Vozil004 (Vehicle Generator-004) is shown in Fig. 4.

The density of distribution is given as a parameter in the entry window, obtained by double clicking on the icon representing the block.

Two functions created in Matlab were used in the design of this block: ExponentnaRND and Izhod. The function EksponentnaRND represents the central part of the block. The vector u, which is multiplexed from two signals, is the function's input, u(1) represents the signal from the feedback loop, while u(2) brings the information on density. The function checks if the value of the feedback signal is less than 0. In this case a new value is calculated to represent the time until the arrival of the next vehicle in seconds. In the opposite case, when u(1) is not less than 0, the value obtained at the output is equal to the one obtained at the input of the function Eksponentna-RND.

After that the signal is branched. It travels to the function Exit where it is checked if the value u is equal to zero. If so, the obtained signal value at the exit is 1 in the duration of 1 second. If not so, the value at the exit remains 0, which means that no new vehicle is generated.

The signal also travels through the feedback loop and stops in the Memory block for one simulation step to prevent the algebraic loop. Every second the signal value is subtracted for one in the adder. This kind of operation is made possible by the sub-unit that returns an impulse of the width of one simulation step every second. Then this reduced signal travels to the input of the multiplexer.

It is obvious that the moment when the value 0 is obtained at the output of the function Eksponentna-RND is crucial. At that moment the function Izhod returns the value 1 for the time of one second, while the signal in the feedback loop is reduced by 1, so that the value -1 is obtained at the input of the function EksponentnaRND, which starts the calculation of the time until the arrival of the next vehicle. The parameter density tells us the average time between the arrivals of two vehicles. This means that, in case of 10 vehicles per minute on the average, we have one vehicle per six seconds on the average. This is the parameter entered as the density.

3. TRAFFIC SIMULATION IN A TRAFFIC LIGHT-CONTROLLED CROSSROAD

The discussed example is a traffic light-controlled crossroad in Murska Sobota, known for its heavy traffic. The traffic is the heaviest from 13 to 16 hours (from 1 to 4 p.m.), i. e. during the rush hours when a long queue of vehicles trying to turn from the Gregorčičeva street to the Panonska street is formed. In accordance with this situation the intervals of traffic lights are set so that within one cycle of 63 seconds the green light in the direction of the Cankarjeva - Panonska street lasts 40 seconds, while the green light in the direction of the Gregorčičeva - Bakovska street lasts only 23 seconds. It should be noted that there are no serious traffic problems at this crossroads outside the rush hours. The impact of pedestrians and cyclists on the traffic is so small that it has been neglected in our analysis.

The generation of vehicles in the model is assumed to follow the exponential distribution. The distribution mean value is given as the input parameter. The queuing of the model is assumed to follow the normal distribution at the mean value of 2 seconds and at the deviation value of 0.4. This means that the vehicles pass through the crossroad in the period of time of 1 to 3 seconds. There are eight traffic lanes in the crossroads, where queues of vehicles are formed depending on the traffic lights. The vehicles and the traffic lights represent the dynamic part of the system. Vehicles enter the crossroad according to the rules of FIFO discipline. As there is only one traffic lane for each direction, and as the traffic lights allow the presence of only two vehicles in the crossroads at the time, the system is described as: M/N/1/2/FIFO (M is the exponential queuing distribution, N is the normal queuing distribution, 1 is the number of queuing locations, 2 is the capacity of the queuing system, and FIFO stands for: first in first out).

The discussed crossroads is shown in Fig. 5

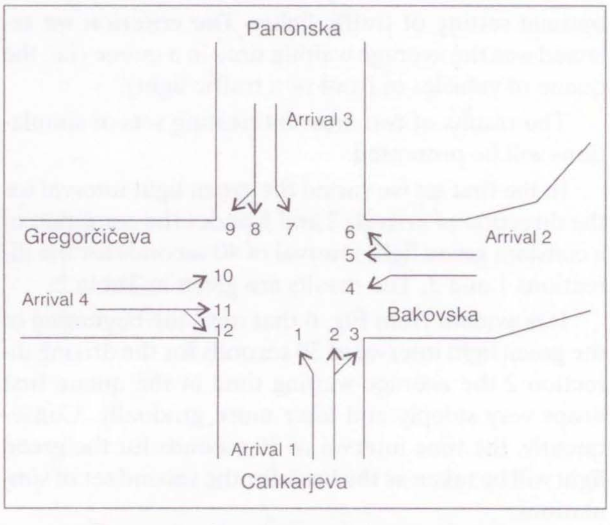

Figure 5 - Simulation of the crossroads

The model is composed of the known elements described in previous sections. The simulation was performed for the period of three hours, covering the

Table 1 - The calculated data on the average density of vehicle arrivals

Driving direction	1	2	3	4	5	6	7	8	9	10	11	12
Traffic loading v	58	9	80	112	23	39	49	12	12	18	24	39

Table 2 - The results of the first set of simulations

Arrivals from the directions 2 - 4	15	23	30	40	50
Arrivals from the directions 1 - 3	40	40	40	40	40
Driving in the direction 2	7.788s	11.79s	14.7s	19.34s	26.24s
Driving in the direction 10	521.6s	45.17s	29.39s	25.02s	21.1s
Description of simulation	/	existing state	/	/	/

Table 3 - Results for the second set of simulations

Arrivals from the directions 2 - 4	30	30	30	30	30
Arrivals from the directions 1 - 3	10	20	30	50	60
Driving in the direction 2	158.6s	21.8s	16.77s	14.03s	12.23s
Driving in the direction 10	9.587s	14.62s	41.64s	56.48s	72.56s
Description of simulation	/	/	/	/	/

rush hours from 1 to 4 p.m. One simulation step was 1 second.

The data on traffic loading, given as the number of vehicles in the discussed period of time, were transformed as required by the vehicle generation block, simply by dividing the simulation time in seconds by the number of vehicles passing through the crossroads at that very time. The results are presented in Table 1.

The obtained results represent the parameters for the corresponding vehicle generation blocks. A number of simulations were performed in order to get the optimal setting of traffic lights. The criterion we selected was the average waiting time in a queue (i.e. the queue of vehicles in front of a traffic light).

The results of two most interesting sets of simulations will be presented.

In the first set we varied the green light interval for the direction of arrivals 2 and 4 under the condition of a constant green light interval of 40 seconds for the directions 1 and 3. The results are given in Table 2.

It is evident from Fig. 6 that until the beginning of the green light interval of 30 seconds for the driving direction 2 the average waiting time in the queue first drops very steeply and later more gradually. Consequently, the time interval of 30 seconds for the green light will be taken as the basis for the second set of simulations.

In the second set of simulations we varied the value of the green light time interval for the directions 1 and 3 under the condition of a constant green light interval of 30 seconds for the directions 2 and 4. The results are shown in Table 3 and Fig. 7.

Fig. 7 shows clearly that it is best to have a green light time interval of approximately 20 seconds for the arrivals from the directions 1 and 3, so 30 seconds are left for the arrivals from the directions 2 and 4. Additional simulations have confirmed these results.

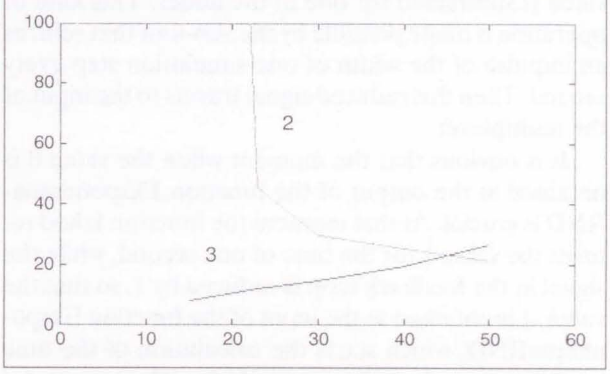

Figure 6 - The results of the first set of simulations

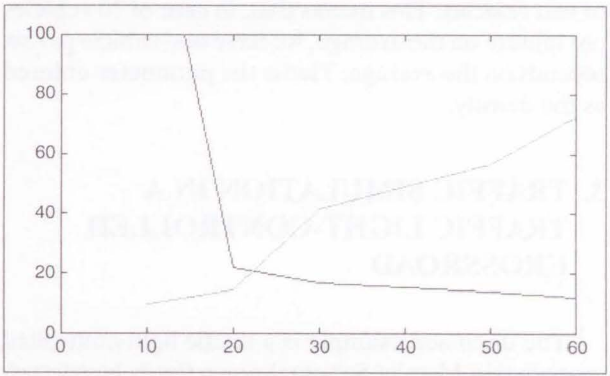

Figure 7 - The results of the second set of simulations

It is evident from the results of simulations that it would be reasonable to introduce at least two operating regimes in the discussed crossroads. During the rush hours from 1 to 4 p.m. the green light interval for the arrivals from the directions 1 and 3 would be 20 seconds, and 30 seconds for arrivals from the directions 2 and 4. During the remaining hours of the day the operating regime would remain unchanged, i.e. 40 seconds for arrivals from the directions 1 and 3, and 23 seconds for arrivals from the directions 2 and 4. The average waiting times could be further reduced by introducing a different traffic light switching regime or by introducing additional traffic lanes.

In Fig. 8 we can see the simulation of arrivals of vehicles in the discussed crossroads for the driving direction 10.

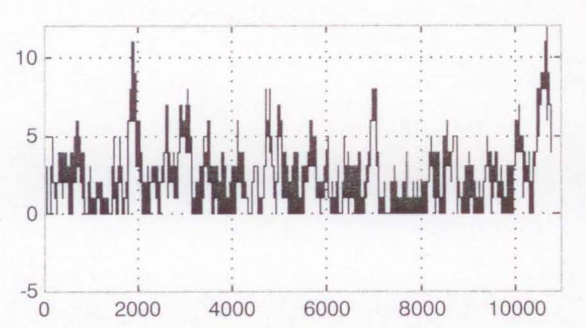

Figure 8 - Queue of vehicles for the driving direction 10

4. CONCLUSION

The described blocks represent a very solid base for modelling and simulation of traffic regimes. If a problem occurs for which no adequate block exists, a new block can be easily made from the existing ones or from the basic blocks offered by the software package Simulink.

We have shown that with the existing blocks it is possible to build a model of a real crossroads, make simulations with real data and get practical results in a few hours. This is a very short period of time that clearly demonstrates the practical value of the presented blocks. To write a program instead would be an extremely time-consuming task.

Many tasks can be fulfilled with the blocks and models described in this paper. The first and the most important function to be implemented in the near future will be the optimisation block. This block will be built to monitor the average waiting time in the queue before the traffic lights and, on the basis of the given criterion, change the output value, i.e. the green light time interval in seconds for individual traffic lights. These data will be sent to the input of traffic lights to create the feedback loop.

POVZETEK

SIMULIRANJE PROMETNIH TOKOV V KRIŽIŠČU

Izjemna množica različnih situacij v prometu posledično povzroča tudi probleme pri iskanju primernega orodja za simuliranje različnih prometnih režimov. Izkazalo se je, da je SIMULINK eden od najboljših orodij za izvajanje tovrstnih simulacij. Članek prikazuje kako oblikovati in uporabljati posamezne komponente in modele v programu Matlab/SIMULINK. Predstavljeni so rezultati izvedene simulacije na primeru semaforiziranega križanja prometnih tokov. Ob tem so zaznamne posamezne možnosti za nadaljno optimizacijo semaforskih nastavitev.

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