CONTROLING AN ISOLATED OVERSATURATED INTERSECTION IN REAL TIME. FUZZY LOGIC APPROACH.

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Abstract:

In this paper we consider a problem of controling an oversaturated intersection in real time. We developed a mathematical model for solving the problem, based on fuzzy logic. The model can be applied to intersections characterized by oversaturated traffic flows. We compared this fuzzy logic approach to the "fixed time" controling of the oversaturated intersection. By "fixed time" we understood controlling based on the hystorical data about traffic flows. In the case of the oversaturated intersection considered in this paper, a classical approach of controlling in real time ("actuated time control") gives the same solutions as "fixed time" control. The criterion function for comparing solutions represents the control delay of all vehicles that pass through the intersection within a certain period of analysis. We tested these approaches on a "T" intersection, where the suggested model based on fuzzy logic generated solutions with less control delay in comparison to the "fixed time" model.

Key words: isolated signalized intersections, oversaturated traffic flows, fuzzy logic, real time control, vehicle control delay.

Introduction

One of the biggest problems faced by the authorities in large cities around the world is the problem of traffic congestion. City authorities allocate significant resources to solve this problem which affects various aspects of life of residents. The negative consequences of traffic congestion are reflected primarily in increased time losses of traffic participants. In addition, the consequences can be economic (higher fuel consumption), ecological (additional air pollution) and many others. Since it is not always possible to build new roads, in order to solve the problem described, traffic engineers apply various control and management measures and strategies to avoid or at least to mitigate traffic congestion. Congestion pricing, park and ride and car sharing are just some of them. The control of the operation of traffic signals has proven to be efficient and at the same time an economically cost effective measure.

In this paper, we consider the problem of managing isolated signalized oversaturated intersections. A mathematical model for controlling an oversaturated intersection, based on the fuzzy logic system "Sugeno" type is developed. The criterion function represents the control delay of vehicles in a certain period of analysis. The proposed model has been compared with "fixed time" control with respect to the values of the criterion function. A simulation approach was used as a comparison method.

Data on traffic flows were obtained from the detector. We considered the case when the intersection is oversaturated in all flows ("full oversaturated intersection"). Such a case is possible in the central zones of large cities, especially in peak periods of traffic load.

Real time management is characterized by dividing time into small intervals, 2 to 5 seconds, after which a decision is made whether to extend the existing phase or to interrupt it. This type of traffic control is characteristic of the following works (Miller, 1963, pp.200-220), (Bang, 1976, pp.288-292), (Vincent & Young, 1986, pp.385-387), (Lin et al, 1987, pp.89-98). There are also approaches where the decision time is longer and their characteristic is a prediction of signal plans for future traffic flows (Gartner, 1983, pp.75-81).

Since Pappis and Mamdani published a paper in 1977 in which they proposed controlling the intersection which consists of two one-way streets based on the fuzzy logic approach (Pappis & Mamdani, 1977, pp.707-717), the interest of traffic engineers for the application of this mode of operation has been growing. An analysis of the use of several types of fuzzy logic management systems for the controling of an isolated intersection was presented in the paper (Jacques et al, 2002, p.81). In this paper, the directions for future development of fuzzy logical systems are given in order to improve the work of the isolated intersection.

In the paper (Murat & Gedizlioglu, 2005, pp.19-36), the implementation of fuzzy logic was demonstrated in order to optimize the schedule of flows in phases. Murat in his work (Murat, 2006, pp.316-334) showed that the problem of controling a signalized intersection can be successfully solved by a hybrid algorithm of neural networks and fuzzy logic. A hybrid model of genetic algorithms and fuzzy logic for the control of flows at an isolated intersection can be found in the paper (Yang et al, 2006, pp.3391-3395). In the paper (Nair & Cai, 2007, pp.1229-1233), a unique fuzzy logic model is developed for controling traffic flows in specific situations at the intersection, such as traffic accidents, works in the intersection zone, etc.

The fuzzy logic system "Mamdani" type for controlling an isolated oversaturated intersection has been developed and shown in the paper (Zhang et al, 2008, pp.179-184). They considered the problem when there are two oversaturated approaches, in a mutual conflict. Other currents are unsaturated. In this case, there is a possibility of application of classical control in real time with the detectors ("actuated time control"). The authors compared their approach with the indicated classic approach, where fuzzy logic was better in all criteria. To compare the results, they used the simulation model proposed in the paper (Li & Prevedouros, 2004, pp.594-601), who developed the TACOST algorithm ("Traffic Adaptive Control for Oversaturated Intersections") by solving the same problem.

The application of simulation and a fuzzy logic system, implemented in MATLAB environment, to the problem of controlling isolated signalized intersections can be found in the work (Soh et al, 2010, pp.924-933). The possibility of using a detector with a camera in the traffic flow control at the intersection in real time is shown in the paper (Diaz-Cabrera et al, 2015, pp.3911-3923). The authors used fuzzy clustering to process the image they get from the camera in the best possible way.

This work is organized in the following way: after the introductory review and a brief review of some of important papers in this field, the second chapter is devoted to setting the problems and goals of this paper. The third chapter provides a methodology for solving a problem based on the fuzzy logical system. In the fourth chapter, the proposed approach was tested on an "T" intersection. A simulation was used to compare the results obtained by the classic approach and the methodology proposed in this paper. Chapter 5 is dedicated to concluding observations and directions for future research.

Setting up problems and goals

This paper examines an intersection that has oversaturated traffic flows at all phases. This intersection is called completely oversaturated and it is different from the ones considered in the paper (Zhang et al, 2008, pp.179-184), where an intersection with two oversaturated flows in mutual conflict is considered.

In the aforementioned work, the authors compared fuzzy logical control with classical detector control. When the intersection is overloaded in practically all streams, "fixed time" management is recommended as it provides the same signaling plans as classical detector control (Roess et al, 2011).

Fuzzy logical systems are managed using linguistic variables that are characterized by unclear boundaries. For example, is it possible to accurately estimate the travel time between two nodes on the transport network or whether it is possible to say precisely for a branch of the network whether it is congested or not, or whether it can be precisely stated what is the degree of that congestion. The answer to these questions is definitely negative. According to the classical theory of sets, the branch of the transport network may either belong to or not belong to a group of congested ones. In other words, the elements of a set can absolutely belong to that set, or absolutely do not belong to it.

Inspired by this kind of thinking, Zadeh in his famous work from 1965 proposed a modified theory of sets (fuzzy sets) in which the membership of a set can be expressed by some percentages, and not only or absolutely belongs (1) or absolutely does not belong (0), see (Zadeh, 1965, pp.338-353). Accordingly, according to this modified theory, sets of branches of the network can with 70% belong to a set of congested branches, and with 30% collection where there is no congestion.

Fuzzy logic is suitable for controlling an oversaturated isolated intersection because it is able to imitate the "ideal" policeman at the intersection. Such a policeman does not count the vehicles, but he/she intuitively knows (feels) when enough cars have been released from one approach while vehicles are piled from the other approach.

The aim of this research is to show that the fuzzy logic approach can be competitive with respect to the classic approach, in conditions of total oversaturation. What is more, using the unevenness of vehicle’s approach during the phase which we analyze, the fuzzy logical system tries to find better signaling plans than a fixed time control strategy. The measure of the quality of the received signaling plans (cycle values and green times per phase) is control delay of the vehicle.

Methodology

The fuzzy logic controller that we developed and present in this paper controls the queues of vehicles based on two input and one output fuzzy set. The first input fuzzy set is the number of vehicles in a queue that is served during the green phase (Vap). The second input fuzzy logic set represents the number of vehicles in a queue waiting for the green time of the next phase (Vq). Fuzzy logical sets are shown in Figure 1. The input fuzzy sets consist of three membership functions represented by Gaussian curves: the small, middle and large order of the vehicle. The limit values for the number of vehicles in a row shown in Figure 1 can be changed depending on the specific intersection.

The developed fuzzy logic system is of a "Sugeno" type and determines at each 2 s whether the existing phase is extended, or is interrupted (EXT). The output size consists of two numbers: 1 if the phase is extended by another 2 s, and 0 if the phase is interrupted.

Each phase has its minimum green time (gmin) and its maximum green time (gmax). The minimum green time is determined based on the distance of the detector from the stop line. More details on determining the minimum green phase time can be found in the book (Roess et al, 2011). The maximum green time is determined by optimization in the case of "fixed time" control. More details about optimization in "fixed time" control can be found in the paper (Jovanović & Teodorović, 2017, pp.556-576).

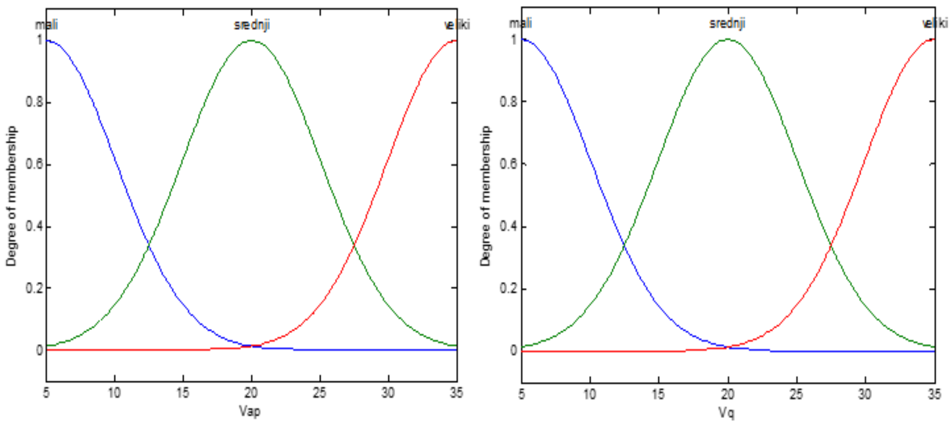

Figure 1 – Input variables into the fuzzy logical system
Рис. 1 – Входные переменные в системе Фаззи-логики
Слика 1 – Улазне величине у фази логички систем

The EXT value has a range of 0 to 1. If the EXT value is greater than or equal to 0.5, the phase is extended; if less than 0.5 the current phase is interrupted. Therefore, each phase can be interrupted either by the decision of the fuzzy logical system or if it has reached its maximum green time. The algorithm for deciding on an extension or phase break is given in Figure 2.

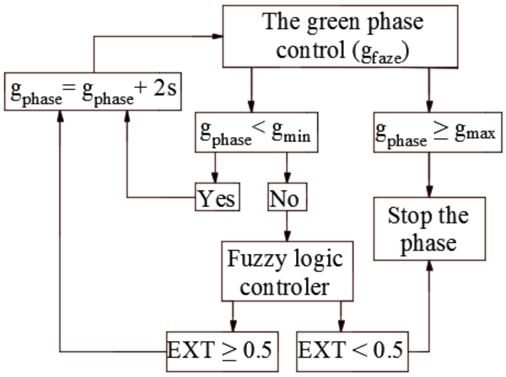

Figure 2 –The algorithm for the control of the green phase time
Рис. 2 – Алгоритмы для управления продолжительностью зеленой фазы
Слика 2 – Алгоритам за управљање зеленим временом фазе

The developed model does not anticipate the skipping of the phases, nor the choice between the several phases to which the green time will be assigned. Considering the subject of the study of this work (the intersection oversaturated in all phases), such changes in the algorithm would not lead to significant improvements in the value of control delay.

The fuzzy logic system is formed based on the ”If-Then" rules. The "If" part of the rule is a premise, while the "Then" part represents a consequence. In this case, the "Then" part of the rule is a binary decision about whether to extend the phase for another two seconds or to interrupt it. The basis of the rule of the phase of the logical system is formed and shown in Table 1.

Table 1 – Fuzzy rules base
Таблица 1 – База фаззи правил
Табела 1 – База фази правила

Serial number	if $\mathbf{V_{ap}}$ (voz) is	and $\mathbf{V_q}$ (voz) is	then **EXT** is	Weight factor
1.	small	small	1	0.8
2.	small	medium	0	0.8
3.	small	big	0	1
4.	medium	small	1	1
5.	medium	medium	1	0.6
6.	medium	big	0	0.8
7.	big	small	1	1
8.	big	medium	1	0.8
9.	big	big	0	0.6

The exit from the logical system stage is the value of EXT, which is between 0 and 1. Based on the value of the EXT size, a decision is made on the extension or interruption of the green phase time (the algorithm in Figure 2). EXT is obtained by defuzzification, which is the last step of the proposed methodology. Defuzzification and the fuzzy logical system are implemented in the program package "MATLAB" 2010, and in its "Toolbox" called "FIS Editor". The "3D" dependence of the input and output variables is shown in Figure 3.

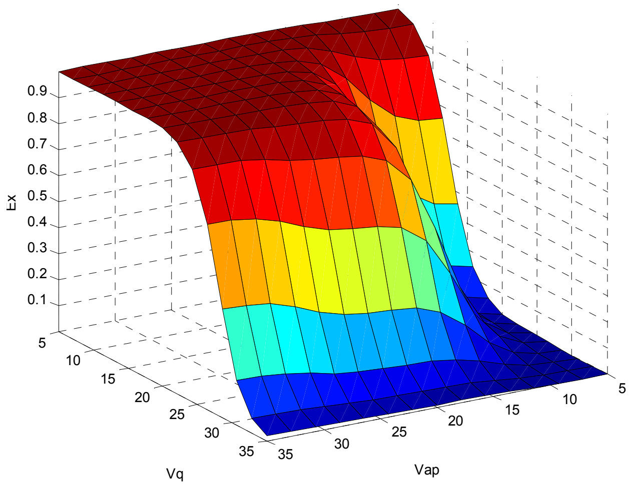

Figure 3 – "3D" dependence of the fuzzy logical system variables
Рис. 3 – "3D" зависимость переменных в системе фаззи-логики
Слика 3 – „3D" зависност променљивих величина фази логичког система

Test example

As a test example, we take a hypothetical "T" intersection with a traffic flow in each approach having its own phase. The intersection is in full mode, with one traffic lane at each approach. Detectors are located at a sufficient distance from the stop line so they can count all vehicles that make up the queue on the access roads.

At every 2 s, the detector sends the binary information to the stage to a fuzzy logical controller in the form of 0 (no new vehicle) or 1 (precisely 1 vehicle appeared). Also, 2 seconds is provided for serving a vehicle (when it leaves the stop line). By this setting, at every 2 seconds the queue of vehicles is updated at each of the intersection approaches, whether the queue has the green time or is waiting for service.

Figure 4 shows the test intersections with the layout of flows in all approaches during the phases. The figure shows a lane traffic flows (veh / h). All red time between all phases is 2 s, within which the detector sends the information whether a new vehicle has joined the queue or not.

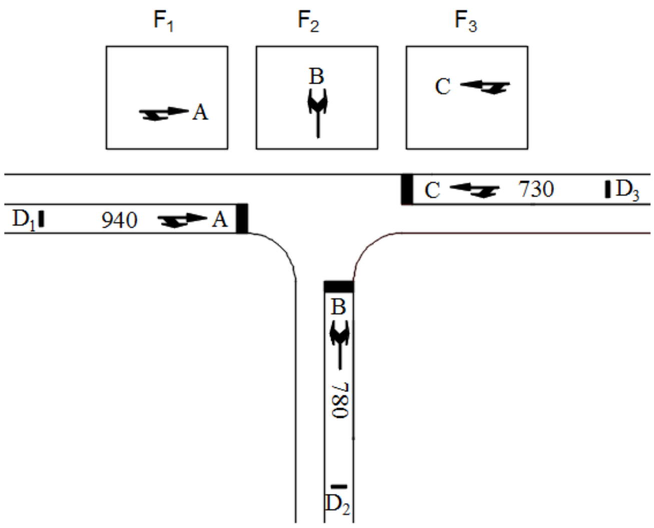

Figure 4 – Test intersection
Рис. 4 – Тест перекресток
Слика 4 – Тест раскрсница

Based on the optimization, a solution with the minimum value of control delays is obtained. This solution implies "fixed time" control. At the same time, the green timing of the phases obtained in this way represents the maximum green time in "real time" control. The solution gives a cycle value of 120 s and a green time value of 40 s, 38 s and 36 s, respectively, in phases. The minimum green time for all phases was adopted at 10 s.

The fuzzy logic controller uses imbalances in the coming of a vehicle during the cycle. The schedule of vehicles approaching in 10 minutes time is given in the Appendix. Vehicle arrival is generated in a random way (Appendix). The solutions offered by the model developed in this paper are presented in the form: C; g1phase, g2phase, g3phase. The following solutions were obtained: 1) 72; 18, 38, 10. 2) 100; 36, 28, 30. 3) 68; 14, 38, 10. 4) 46; 10, 20, 10. 5) 120; 40, 38, 36. 6) 112; 40, 30, 36. In the last, seventh cycle, phase 3 was not tested because the analysis period, which was 10 minutes, expired. The time for phase 1 and 2 was obtained from 40 s and 10 s, respectively, while the interrupted phase 3 was 28 s. In this case, it can be concluded that the incomplete cycle was 82 s, with the cycle lost time of 4 s.

Simulation

In order to test the performance of the generated solutions, a simulation model has been developed to calculate the control delay of the vehicle. The basic geometric model on which the calculation of control delay of vehicles is based, given by (Akçelik, 1980) and the model assumes that the arrival of the vehicle during the cycle is constant. Within the framework of the developed simulation, in this paper, vehicle flows vary from phase to phase, which reflects the real situation at the intersection more closely.

In this case, vehicles are served within three phases, with the initial queues of unserved vehicles from the previous cycle. The total control delays during the k-cycle are obtained by calculating the surface of the highlighted parts in Figure 5. The total control delays per cycle are divided by vehicle flows (A, B and C of Figure 4). In the further test, the equations will be given only for the flow of the vehicle A, while the control delay for flows B and C are calculated analogously to that.

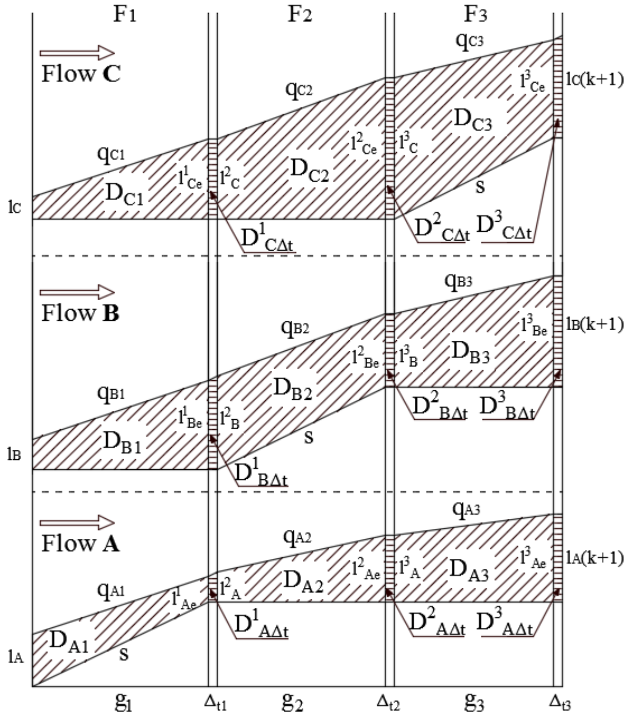

Figure 5 – The calculation of the control delays during the kth cycle
Рис. 5 – Расчет потерь времени в течение „к“ цикла
Слика 5 – Прорачун временских губитака током к-тог циклуса

The control delays for phases 1, 2, and 3, during the k cycle, are denoted by D_{A1} *(k)*, D_{A2} *(k)* and D_{A3} *(k)*, respectively. They are counted as follows:

$$D_{A1}(k) = \frac{1}{2} \cdot \left(l_A(k) + l^1_{Ae}(k)\right) \cdot g_1(k)$$

$$D_{A2}(k) = \frac{1}{2} \cdot \left(l^2_A(k) + l^2_{Ae}(k)\right) \cdot g_2(k)$$

$$D_{A3}(k) = \frac{1}{2} \cdot \left(l^3_A(k) + l^3_{Ae}(k)\right) \cdot g_3(k)$$

where we denoted: l_A *(k)* – number of vehicles in the flow *A* at the beginning of the kth cycle, g_1 *(k)*; g_2 *(k)*; g_3 *(k)* – green time for phases 1, 2 and 3 in the kth cycle. The number of vehicles in the flow *A* at the end of phases 1, 2 and 3 in the kth cycle: l^1_{Ae} *(k)*; l^2_{Ae} *(k)* i l^3_{Ae} *(k)* is calculated in the following way:

$$l^1_{Ae}(k) = l_A(k) + q_{A1} \cdot g_1(k) - g_1(k) \cdot s$$

$$l^2_{Ae}(k) = l^2_A(k) + q_{A2} \cdot g_2(k)$$

$$l^3_{Ae}(k) = l^3_A(k) + q_{A3} \cdot g_3(k)$$

In the proposed simulation, we consider the case when s is constant and equal to ½ for each vehicle approach. Calibration of the model is possible also for different values of s in different approaches.

After completing one phase, the model does not switch to the next one immediately, but there is also the protection time Δt. Within this time, the detector can register a new vehicle. Accordingly, the following binary variable is introduced:

$$\delta_F = \begin{cases} 1 \text{ if at the end of the phase F detector} \\ \text{register the vehicle in the time } \Delta\text{t}, \\ 0 \text{ othervise.} \end{cases}$$

The numbers of the vehicles in the approach *A* at the beginning of the phases 2 and 3 in the kth cycle l^2_A *(k)* and l^3_A *(k)*, and the number of unserved vehicles during the kth cycle (represent the initial queue at the beginning of the *k+1*-st cycle): l_A *(k+1)* are calculated in the following manner:

$$l^2_A(k) = l^1_{Ae}(k) + \delta_F$$

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$$l_A^3(k) = l_{Ae}^2(k) + \delta_F$$

$$l_A(k+1) = l_{Ae}^3(k) + \delta_F$$

The control delays for the approach *A* during the protected time *Δt*: $D^1_{A\Delta t}(k)$; $D^2_{A\Delta t}(k)$ i $D^3_{A\Delta t}(k)$, for phases 1, 2 and 3, respectively, are obtained from the next calculations:

$$D_{A\Delta t}^1(k) = \frac{1}{2}\cdot\left(l_{Ae}^1(k) + l_A^2(k)\right)\cdot\Delta t_1$$

$$D_{A\Delta t}^2(k) = \frac{1}{2}\cdot\left(l_{Ae}^2(k) + l_A^3(k)\right)\cdot\Delta t_2$$

$$D_{A\Delta t}^3(k) = \frac{1}{2}\cdot\left(l_{Ae}^3(k) + l_A(k+1)\right)\cdot\Delta t_3$$

In this case, the time Δt is 2s for all phases. This value is constant throughout the entire simulation. In other words, the Δt times are the same during all k cycles.

Denote by $D_A(k)$ control delays for approach *A* during the *k*th cycle. Then, we finally obtain:

$$D_A(k) = D_{A1}(k) + D_{A2}(k) + D_{A3}(k) + D^1_{A\Delta t}(k) + D^2_{A\Delta t}(k) + D^3_{A\Delta t}(k).$$

Results

For the data presented at the beginning of the fourth chapter, control delays of vehicles are generated in the case of fixed-time control (FTC) and also for the fuzzy logical time controller (FLTC). The values for 10 minutes of simulation are shown in Figure 6.

After 10 minutes of simulation, the control delays of vehicles in the case of FTC control were 66 853 s, while in the case of FLTC control they were 58 468 s. Fuzzy logic gave better results for 8 385 s, or 12.54%.

If with CVD (s) we denote the control delays generated during the simulation, and with Q_1, Q_2 and Q_3, the total number of vehicles per phase (data given in Figure 4), the average control delays of the vehicle (ACVD (s / veh)), during the simulation, are obtained as follows:

$$ACVD = \frac{6\cdot CVD}{Q_1 + Q_2 + Q_3}$$

Accordingly, the average control delays of the vehicles in the case of FTC control were 164 s / veh, while in the case of FLTC they were 143 s / veh. Fuzzy logic gave better results for 21 s / veh.

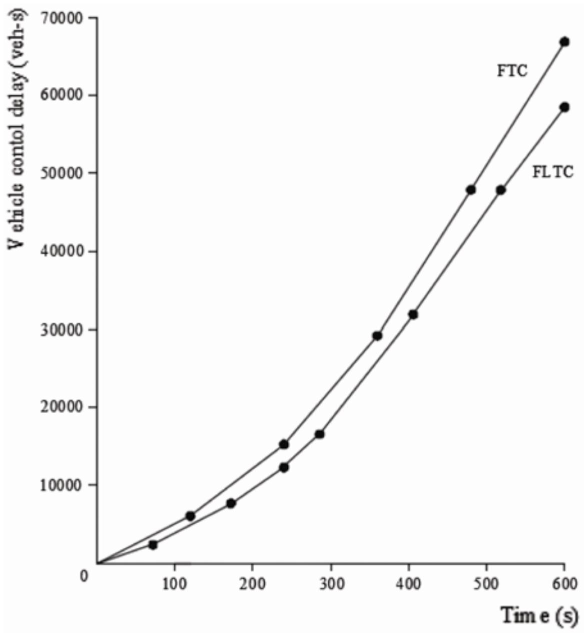

Figure 6 – The simulation results
Рис. 6 – Результаты моделирования
Слика 6 – Резултати симулације

Conclusion

In this paper, the fuzzy logical model of the Sugeno type for controlling an isolated oversaturated intersection in real time has been developed. The intersection is oversaturated, so there are unserved queues of vehicles at the end of the cycle in all approaches (fully oversaturated intersection).

For an intersection characterized by such oversaturation, it is recommended that it should be controlled using a fixed-time strategy and fixed green-time in all phases. If it were controlled by the classic detector strategy, the same values of cycles and green times would be obtained, as well as in the case of fixed-time control.

Using the unevenness of the vehicle arrivals, the fuzzy logical controller developed in this paper succeeds in generating different cycle and green time values in phases. Control delays, tested on a numerical example, are less than 12.54% for the fuzzy logic control compared to fixed time control. Control delays are calculated during a ten-minute simulation, which is specially developed for the purpose of this paper.

The directions of future research could go towards the application of the proposed model to the coordinated work of traffic signals, both for linear and zonal coordination. Also, consideration could be given to improving the results by optimizing the membership functions of the fuzzy logical system or the fuzzy rules.

References

Akçelik, R., 1980. Time-dependent expressions for delay, stop rate and queue length at traffic signals. In: *International Report AIR 367-1*. Vermont South, Australia: Australian Road Research Board.

Bang, K.L., 1976. Optimal control of isolated traffic signals. *Traffic Engineering and Control,* 17(7), pp.288-292.

Diaz-Cabrera, M., Cerri, P., & Medici, P., 2015. Robust real-time traffic light detection and distance estimation using a single camera. *Expert Systems with Applications,* 42(8), pp.3911-3923. Available at: https://doi.org/10.1016/j.eswa.2014.12.037.

Gartner, N.H., 1983. OPAC: A demand-responsive strategy for traffic signal control. *Transportation Research Record,* 906, pp.75-81.

Jacques, M.A.P., Niitymaki, J., & Pursula, M., 2002. Analyzing different fuzzy traffic signal controllers for isolated intersections. In: Transportation Research Board 81st Annual Meeting, p.81.

Jovanović, A., & Teodorović, D., 2017. Pre-timed control for an under-saturated and over-saturated isolated intersection: A Bee Colony Optimization approach. *Transportation Planning and Technology,* 40(5), pp.556-576. Available at: http://dx.doi.org/10.1080/03081060.2017.1314498.

Li, H., & Prevedouros, P.D., 2004. Traffic adaptive control for oversaturated isolated intersections: Model development and simulation testing. *Journal of Transportation Engineering,* 130(5), pp.594-601.

Lin, F.B., Cooke, D.J., & Vijayakumar, S., 1987. Use of predicted vehicle arrival information for adaptive signal control: An assessment. *Transportation Research Record,* 1112, pp.89-98.

Miller, A.J., 1963. A computer control system for traffic networks. In: Proceedings of the 2nd International Symposium on the Theory of Traffic Flow. London, pp.200-220.

Murat, S., 2006. Comparison of fuzzy logic and artificial neural networks approaches in vehicle delay modeling. *Transportation Research Part C,* 14(5), pp.316-334. Available at: http://dx.doi.org/10.1016/j.trc.2006.08.003.

Murat, S., & Gedizlioglu, E., 2005. A fuzzy logic multi-phased signal control model for isolated junctions. *Transportation Research Part C,* 13(1), pp.19-36. Available at: http://dx.doi.org/10.1016/j.trc.2004.12.004.

Nair, B.M., & Cai, J., 2007. A fuzzy logic controller for isolated signalized intersection with traffic abnormality considered. In: IEEE intelligent vehicles symposium. IEEE, pp.1229-1233.

Pappis, C.P., & Mamdani, E.H., 1977. A Fuzzy Logic Controller for a Trafc Junction. *IEEE Transactions on Systems, Man, and Cybernetics,* 7(10), pp.707-717. Available at: http://dx.doi.org/10.1109/TSMC.1977.4309605.

Roess, R.P., Prassas, E., & McShane, W.R., 2011. *Traffic engineering, 4th ed*. Upper Saddle River, N.J.: Prentice Hall.

Soh, A.C., Rhung, L.G., & Sarkan, H.M., 2010. MATLAB simulation of fuzzy traffic controller for multilane isolated intersection. *International Journal on Computer Science and Engineering,* 2(4), pp.924-933.

Vincent, R.A., & Young, C.P., 1986. Self-optimizing traffic signal control using microprocessors: The TRRL ‘‘MOVA" strategy for isolated intersections. *Traffic Engineering Control,* 27(7/8), pp.385-387.

Yang, Z., & et al, 2006. Multi-phase traffic signal control for isolated intersections based on genetic fuzzy logic. In: 6th World Congress on Intelligent Control and Automation, 1, pp.3391-3395.

Zadeh, L.A., 1965. Fuzzy Sets. *Information and Control,* 8, pp.338-353.

Zhang, L., Li, H., & Prevedouros, P.D., 2008. Signal control for oversaturated intersections using fuzzy logic. In: *Transportation and Development Innovative Best Practices*, pp.179-184.

Appendix: The vehicles’ approaches

faza	s / inicijalni	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
F1	12	0	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	0	0	0	1	1	0	0	0	0	1	1	0	1	1
F2	7	1	0	1	1	1	0	1	0	1	0	1	1	1	1	1	0	1	0	0	1	1	1	0	1	1	1	0	0	1	0
F3	5	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1
		62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
		1	0	0	1	0	1	0	0	1	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
		1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	0	1	1	1	1	0	1	1	0	0
		1	1	1	0	1	0	1	0	0	1	0	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	1	1	1	1
		122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	180
		1	1	0	0	0	1	1	0	0	0	1	0	1	1	0	0	0	0	1	1	1	0	1	0	1	0	0	1	1	1
		1	0	1	1	0	0	0	0	1	1	1	1	0	1	0	1	1	1	1	0	0	1	0	0	1	0	0	1	0	1
		0	1	1	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		182	184	186	188	190	192	194	196	198	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240
		1	1	0	0	0	1	0	1	0	0	1	0	0	1	1	1	0	1	0	0	0	0	1	0	1	1	0	1	0	0
		0	0	1	0	0	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1
		0	1	0	0	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0
		242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284	286	288	290	292	294	296	298	300
		1	1	1	0	0	1	0	0	1	1	0	0	1	0	1	0	1	1	0	0	1	0	1	1	1	0	0	1	1	1
		1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1	0	1	0	1	1	1	0	0	1	1	0
		1	1	0	1	0	0	1	1	1	0	0	1	0	0	1	1	0	1	0	0	1	1	1	1	1	0	0	1	0	1
		302	304	306	308	310	312	314	316	318	320	322	324	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360
		0	1	1	1	1	1	0	1	1	1	0	1	0	1	0	1	1	0	0	1	1	0	1	1	0	1	0	1	1	0
		1	0	1	1	1	1	0	1	1	1	0	0	0	1	0	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1
		0	1	0	0	0	0	1	1	1	1	0	1	0	1	1	0	0	1	0	0	0	1	0	1	1	1	1	0	0	1
		362	364	366	368	370	372	374	376	378	380	382	384	386	388	390	392	394	396	398	400	402	404	406	408	410	412	414	416	418	420
		1	0	1	1	0	1	0	1	0	0	1	1	1	1	0	0	0	1	1	0	1	1	0	1	0	1	0	0	1	1
		0	1	0	0	0	1	0	1	0	1	1	0	0	1	0	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0
		0	1	1	1	1	1	0	1	0	0	0	0	1	1	1	0	0	1	1	1	1	0	0	1	0	1	1	0	0	0
		422	424	426	428	430	432	434	436	438	440	442	444	446	448	450	452	454	456	458	460	462	464	466	468	470	472	474	476	478	480
		0	0	1	0	0	0	1	1	1	0	0	0	1	1	0	1	1	0	1	1	1	1	1	0	0	1	0	0	1	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	0	0	0	1	1	1	1	1	0	1	0	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0
		482	484	486	488	490	492	494	496	498	500	502	504	506	508	510	512	514	516	518	520	522	524	526	528	530	532	534	536	538	540
		0	0	0	1	1	1	0	0	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	0
		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	1	1	0	1	1	0	0	1	1	1	1	0	0	1	0
		542	544	546	548	550	552	554	556	558	560	562	564	566	568	570	572	574	576	578	580	582	584	586	588	590	592	594	596	598	600
		1	1	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	0	1	1	0	1	0	1
		0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	1	0	1	0	0	0	0	0	0	1	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0

УПРАВЛЕНИЕ ИЗОЛИРОВАННЫМ ЗАГРУЖЕННЫМ ПЕРЕКРЕСТКОМ В РЕАЛЬНОМ ВРЕМЕНИ. МЕТОД ФАЗЗИ-ЛОГИКА.

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ОБЛАСТЬ: математика, информатика, дорожное движение
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной работе рассматривается проблема управления светофором на изолированном перекрестке в реальном времени. В статье представлена разработанная на основании фаззи-логики математическая модель, которую можно использовать в подобных ситуациях. Данная модель специально разработана для регулирования перекрестка с загруженным транспортным потоком. Разработанный метод сравнивается с управлением загруженным перекрестком методом «фиксированного времени». Метод «фиксированного времени» подразумевает управление на основании базы данных о транспортном потоке. В случаях загруженности перекрестка, о которых идет речь в данной статье, применяется метод «реального времени», который по результатам не уступает методу «фиксированного времени» управления. Функция сравнительных критериев представляет суммарную потерю времени всех транспортных средств, проезжающих перекресток в течение проведения анализа. Методы были испытаны на перекрестке «Т», результаты тестирования показали, что модель, основанная на фаззи-логике дала решения с меньшими значениями критериев функций в анализируемом промежутке времени, по сравнению с прочими методами.

Ключевые слова: изолированный перекресток со светофором, загруженный транспортный поток, фаззи-логика, управление в реальном времени, потери времени транспортных средств.

УПРАВЉАЊЕ ИЗОЛОВАНОМ ПРЕЗАСИЋЕНОМ РАСКРСНИЦОМ У РЕАЛНОМ ВРЕМЕНУ (ПРИСТУП ФАЗИ ЛОГИКОМ)

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ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду је разматран проблем управљања изолованом семафорисаном раскрсницом у реалном времену. Развијен је математички модел за решавање предметног проблема који је базиран на фази логици. Модел се односи само на раскрсницу коју карактеришу презасићени саобраћајни токови. Приступ решавању предметног проблема поређен је са „fihed time" управљањем презасићеном раскрсницом. "Fihed time" подразумева управљање на основу података о саобраћајним токовима. У случају презасићене раскрснице класничан приступ управљања у реалном времену („actuated time control") даје иста решења као и „фихед тиме" управљање. Критеријумска функција за поређење решења представља укупне временске губитке свих возила која прођу раскрсницом у одређеном периоду анализе. Приступи су тестирани на „Т" раскрсници, где је модел заснован на фази логици генерисао решења са мањом вредношћу критеријумске функције у односу на остале приступе, у одређеном периоду анализе.

Кључне речи: изолована сигналисана раскрсница, презасићени саобраћајни токови, фази логика, управљање у реалном времену, временски губици возила.

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