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TRAFFIC LIGHT REGULATION CALCULATION USING FUZZY INFERENCE

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Abstract.

The problems of traffic flow modeling development theory were considered, the analysis of traffic models as well as the factors for the study of traffic processes. They formulated the base of rules, which allows to draw the conclusion about the relationship of traffic flow parameters and a green signal duration of traffic lights. The model of fuzzy inference was developed based on the basic parameters of a traffic flows. This model allows the use of different cycles set, depending on the existing situation on the area of a city road network. The conclusions about the feasibility of the proposed model were made. Due to the rapid growth of car ownership the developed model may still be applied during the reconstruction of the existing road network, as well during the planning of a new urban scheme; it allows to manage traffic, and consequently, it reduces traffic jam lines, increases the capacity and decreases the loss of time spent for driving, to the environmental condition improvement and fuel consumption reduction.

Keywords. Vehicle, traffic jam, road network, traffic modeling, fuzzy modeling.

Introduction. The growth of vehicular traffic and the impossibility of a road network (RN) reconstruction is one of the major issues of capacity increase. These factors have both positive and negative aspects.

Negative factors include traffic jams, which lead to the loss of time on the road, the deterioration of people health, the negative impact on the environment, etc. Traffic jam is close to a stationary or a stationary state of traffic moving at medium speed, significantly lower than the normal speed for a road segment [1].

The existing problems in the theory of traffic flows was studied and considered by numerous researchers of different areas of expertise - physicists, mathematicians, transit people, economists. A considerable experience is accumulated concerning the study of traffic processes. Despite this, the transport process is poorly understood considering the following factors:

- a transport stream is diverse and unstable, the obtaining of objective information about it is the most complex and resource-intensive element of a control system;
- the criteria of traffic management quality are contradictory ones: it is necessary to ensure the continuity of movement minimizing the losses from transport delays, imposing the restrictions on traffic speed and direction;
- despite its stability road conditions are unpredictable both in terms of deviations from climatic parameters and in terms of stochastic changes in RN parameters;
- the implementation of decisions concerning traffic management is always inaccurate and taking the nature of the traffic process, it leads to unintended effects [2, 3, 4].

These factors discredit any attempts of an analytical description concerning the laws of traffic flows and require an active search for alternative methods of research, including modeling.

Nowadays there is a large number of works on the study and modeling of road traffic flows [5, 6]. Such magazines as Transportation Research, Transportation Science, Mathematical Computer Simulation, Operation Research, Automatica, Physical Review E, Physical Reports also study the transport processes.

Thus, it can be argued that the field of research related to the modeling of transport flows, can be regarded as a relevant and a modern one.

Many models, along with numerous benefits have significant disadvantages, which allow not to take into a full account the main characteristics of a traffic flow, eventually providing an unfinished character in the simulation of a traffic flow [7, 8].

In this study, we will apply the theory of fuzzy sets. The basic ideas of this theory were proposed by the American mathematician Lotfi Zadeh more than 35 years ago. This theory allows to describe the qualitative, imprecise concepts, as well as the knowledge about the world, to operate with the obtained values in order to have new information. The methods of information model development greatly expand the traditional scope of computer application and develop an independent direction of scientific and applied research. This area is called - fuzzy modeling.

Recently, fuzzy modeling is one of the most useful and promising areas of applied studies in the field of management and decision-making. Fuzzy modeling becomes particularly important and useful when the description of technical systems and business processes has some uncertainty which impedes or excludes the application of precise quantitative techniques and approaches.

Fuzzy logic is the basis for the implementation of fuzzy control methods, it describes more naturally the nature of a human mind and the course of its reasoning, than the traditional formal-logical systems. That is why the study and the use of mathematical tools for the provision of fuzzy initial information allows you to develop the models which reflect the various aspects of uncertainty, constantly present in the reality around us most accurately [9].

Methods. The development and the application of fuzzy inference system includes a number of stages, the implementation of which is carried out by the means of fuzzy logic main provisions [10].

1. Fuzzification: the development of a transition procedure from the clear values of the input variables to the fuzzy ones. The choice of a belongiong function (BF) type and its mutual arrangement concerning the input linguistic variables.

2. The development of rule base structure: the development of agreed sets concerning regulator input-output relations.

3. Aggregation: the development of determination procedure concerning the degree of truth conditions for each of the rules.

4. Activation: the development of determination procedure concerning the degree of conclusion truth for each of the rules.

5. Accumulation: the development of integration procedure concerning the degrees of conclusion truth within the whole base of rules.

6. Defuzzification: the development of transition procedure from the fuzzy value of an output variable to a clear one.

Main Part. After the examination of the selected NR portion, on which traffic jams occur regularly, it was decided to consider the efficiency of the traffic light control in order to reveal the relationship between the intensity of vehicular traffic (VT) and a green signal duration of a traffic light.

In our studies, three input linguistic variables were taken for a fuzzy control model by traffic lights (TL), which form an input vector [betta] = [[$betta_1$], [$betta_2$], [$betta_3$], and one output linguistic variable [$betta_4$],

Where [$betta_1$] - the number of vehicles accumulating during a red signal;

[$Betta_2$] - the rate of vehicle number change accumulating during a red signal;

[$Betta_3$] - the ratio of a tire adhesion with a road surface;

[$Betta_4$] - a green signal duration.

FP are introduced for the description of each variable uniformly distributed over the entire range of changes.

For the first linguistic variable [$betta_1$], the values of which are determined from the statistical data:

- VS (Very Small) – [0; 0; 5; 22];
- S (Small) – [0; 22; 44];
- M (Medium) – [22; 44; 66];
- B (Big) – [44; 66; 88];
- VB (VeryBig) – [66; 83; 88; 88].

Figure 1 demonstrates FP for the linguistic variable [$betta_1$] «The number of vehicles accumulating during a red signal". The data concerning the number of vehicles were collected as a result of the experiment, which was conducted during the year.

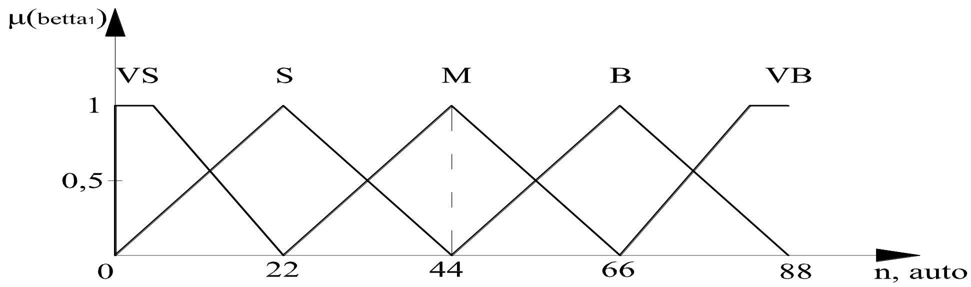

Figure 1 - The functions of belonging for a linguistic variable.

[$betta_1$] “The number of vehicles accumulated during a red signal”

Similarly, the terms are determined on the basis of statistical data for the other linguistic variables.

Based on the conditions of TL control signals development, we accept the range of the output linguistic variable [$betta_4$] in the range [20; 72]. 5 FP are entered in order to describe the variable [$betta_4$]. These FP are uniformly distributed across the whole range of changes:

- VS (Very Small) – [20; 20; 23; 33];
- S (Small) – [20; 33; 46];
- M (Medium) – [33; 46; 59];
- B (Big) – [46; 59; 72];
- VB (Very Big) – [59; 69; 72; 72].

Figure 2 demonstrates FP for the linguistic variable [betta4] “green signal duration”.

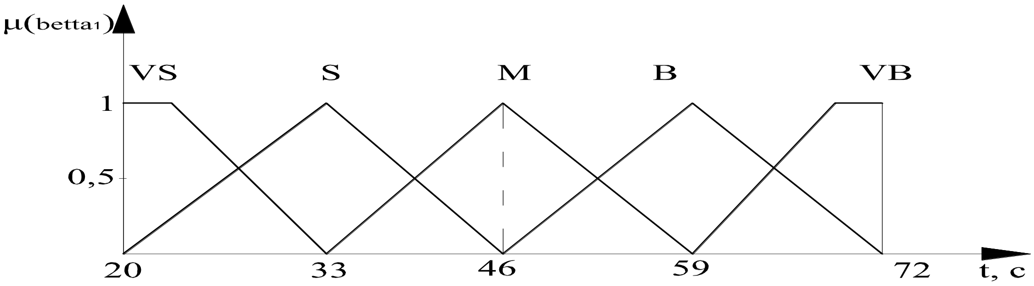

Figure 2 – FP for linguistic variable [betta$_4$].

«Green signal duration»

Then we develop the base of fuzzy rules. There are many different ways to develop the fuzzy rules during a fuzzy model creation. The quickest and the easiest way is based on the study of a management system operation and operator action modeling experience to achieve the set goals, i.e. it is not required to perform analytical calculations in order to generate a control action.

In general, the rule of fuzzy products is as follows:

$$(i):Q;P;A\Rightarrow B;S,F,N,$$

where (i) is the name of the fuzzy production; Q – the field of fuzzy production application; P – the condition of fuzzy product core applicability; A – the condition of the core (or antecedent); B – the core conclusion (or consequent); "$\Rightarrow$" – logical sequence sign (or consequence); S – the method or the way to quantify the degree of truth for a core conclusion; F – certainty or confidence factor for fuzzy production; N – the postconditions of products.

In our case, 125 rules of fuzzy production are developed for SO control system on the basis of statistical data obtained as the result of measurements.

Let's demonstrate five typical fuzzy inference rules as an example:

1) IF[betta$_1$] = VS AND[betta$_2$] = NB AND[betta$_3$]= VS TO[betta$_4$]= S;

2) IF[betta$_1$] = S AND[betta$_2$]= PS AND[betta$_3$]= BTO[betta$_4$]= M;

3) IF [betta$_1$] = B AND [betta$_2$]= Z AND [betta$_3$]= BTO[betta$_4$]= M;

4) IF [betta$_1$]= VB AND [betta$_2$]= NS AND [betta$_3$]= VBTO[betta$_4$]= B;

5) IF [betta$_1$] = VB AND [betta$_2$]= PB AND [betta$_3$]= VBTO[betta$_4$]= VB.

The first rule can be interpreted in a natural language as follows: If "The number of vehicles accumulating during a red signal» [betta$_1$] is very small (VS) and "The pace of vehicle number change accumulated during a red signal» [betta$_2$] is the negative big (NB) and "The coefficient of tire adhesion with a road surface" [betta$_3$] is very small (VS), THEN "The green signal duration» [betta$_4$] is small (S).

The development of the fuzzy output surface for the developed fuzzy model [betta$_4$] «Green signal duration" is implemented in Matlab system.

There is a special FuzzyLogicToolbox package in order to implement a fuzzy output system in Matlab environment. It includes the following graphical tools to edit the elements of fuzzy inference systems:

1. The editor of fuzzy inference systems FIS;

2. FP Editor of fuzzy inference systems (MembershipFunctionEditor);

3. The editor of rules for fuzzy inference system (RuleEditor);

4. The viewer of rules for fuzzy inference system (RuleViewer);

5. The viewer fuzzy inference system surface (SurfaceViewer).

FIS Editor is the primary tool for the creation and editing of fuzzy inference systems in a graphical mode. The graphic interface of FIS editor is shown on Figure 3.

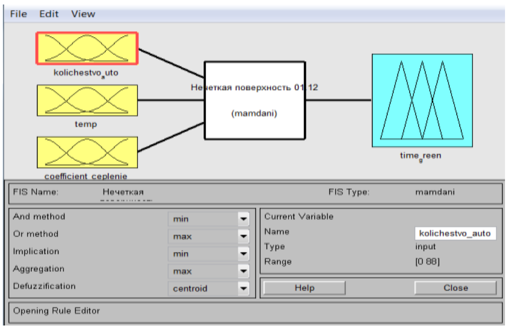

Figure 3 – Graphic interface of FIS editor.

In the bottom part of the FIS editor window you need to select the algorithms of fuzzy logical multiplication and addition. Let's determine the algorithm min for fuzzy logical multiplication and the algorithm max for fuzzy logical addition. Then FP terms are determined using Matlab editor for each of the variables concerning fuzzy inference system. The graphic interface of FP editor for an input variable is shown on Figure 4.

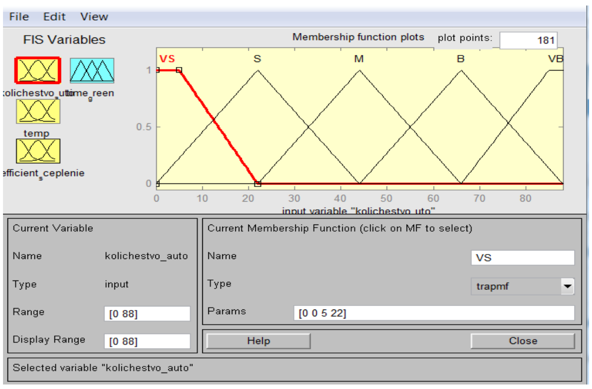

Figure 4 - Graphical interface of FP editor for the input variable "The number of vehicles".

FP are developed similarly for the remaining variables. In order to set 125 rules for the developed fuzzy inference system the Matlab system rule editor is applied. The weighting ratio for each rule is equal to one. The relation of sub-conditions in the rules of fuzzy production is performed using the operations of logical multiplication.

In order to evaluate the work of the developed fuzzy inference system it is necessary to open the Matlab system rule viewer for SO control and enter the values of the input variables.

Summary. The result of SO control signal calculation based on fuzzy inference is illustrated in the following example: [$betta_1$] = 44 - the number of vehicles; [$Betta_2$] = 5 - this indicates that the pace of intensity change has a different character; [$Betta_3$] = 0,4 - the value of friction ratio. The result of fuzzy inference process is that [$betta_4$] = 47 - a control signal. The graphic interface of rule viewer after the performance of fuzzy inference procedure is shown on Figure 5.

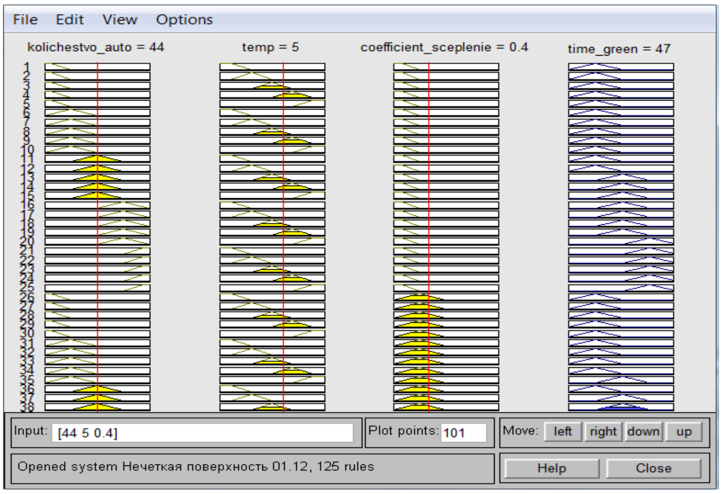

Figure 5 - Graphic interface of rule viewer after the performance of fuzzy inference procedure

The visualization of the respective fuzzy inference surface is useful for the general analysis of the developed fuzzy control model.

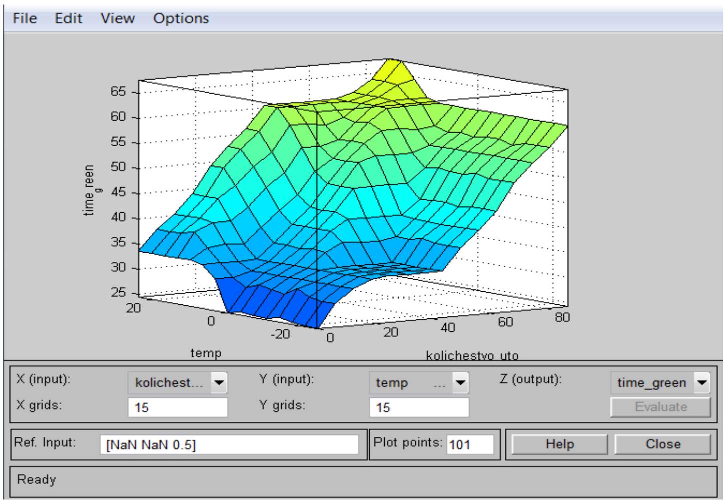

Figure 6 – Fuzzy output surface

Summary. Thus, the problem of a control signal obtaining for SO can be solved using a fuzzy inference system. The surface of fuzzy inference presented on Figure 6, allows you to set the dependence of the value for the output variable betta4 from the input variables [$betta_1$], [$betta_2$] and [$betta_3$] of the fuzzy model within SO control system. This dependence can be the basis for the controller programming or a hardware implementation of the corresponding fuzzy control algorithm in the form of a decision table.

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