SYNTHESIS AND ANALYSIS OF DECISION PROCESSES FOR THE AUTOMATION CONTROL SYSTEM WITH UNCERTAINTY. PART I.

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In this paper, the synthesis and analysis of decision processes of the automation control system with uncertainty are presented. This synthesis and analysis is realized by means of the fuzzy control unit.

1. INTRODUCTION

At the present time, the decision processes of the automation control system (ACS) take place with great number of dependent factors. These factors can be expressed by a quick change, incompleteness and disproportion. Decision processes deal with knowledge and data characterized by uncertainty [1,2].

One of the possible approaches to the decision processes in these systems is to use fuzzy logic (FL). The topic of the paper is the synthesis and analysis of decision processes of ACS with the help of FL, by means of fuzzy control unit (FCU).

2. PROBLEM FORMULATION

Let positions of targets $T_i=\{x_{Ti}, y_{Ti}\}$ and means of combat $M_j=\{x_{Mj}, y_{Mj}\}$ shown in Fig. 1 for the model of decision processes of ACS [1,2] in the rectangular level coordinate system are given.

The horizontal distance from the position T_i to the position M_j is defined as $d_{i,j}$ and direction parameter $P_{i,j}$ is defined as the minimum of horizontal distance between the direction of the movement and position M_j. The decision processes assign the means of combat M_j to the target T_i on the basis of minimum value $d_{i,j}$, $P_{i,j}$ is realized in the model of decision processes of ACS. It satisfies the following conditions:

- $d_{i,j} \in \langle d_{j\,min}, d_{j\,max} \rangle$, where $d_{j\,min}$ ($d_{j\,max}$) is the minimal (maximal) horizontal distance of the means of combat M_j, which must be assigned to the target T_i within this closed interval;
- $| P_{i,j} | \leq P_{j\,max}$, that $P_{j\,max}$ is the maximum direction parameter of the means of combat M_j.

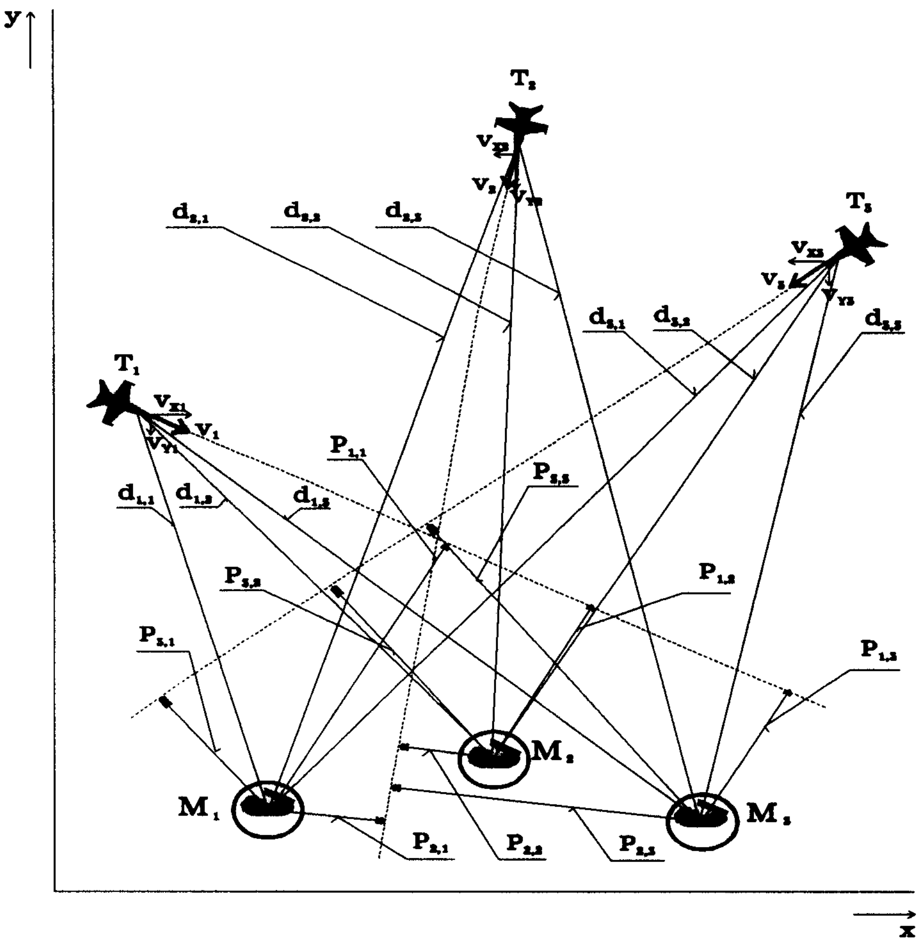

Fig. 1. The model of decision processes of ACS

The model of the decision processes can be designed with input variables $d_{i,j}$ and $P_{i,j}$ according to [1,2] and according to expert knowledge so that:

$$40\ [km] \leq d_{i,j} \leq 60\ [km] \quad \text{and} \quad -18\ [km] \leq P_{i,j} \leq 18\ [km]. \qquad (1)$$

Under the requirement of maximum efficiency of target destruction by decision improvement of assignement of means of combat it can be stated that it is perspective to solve ACS by the system on the basis FL [3,4,5,6,7,8,9] which consider uncertain setting of condition in real time.

3. SYNTHESIS AND ANALYSIS OF DECISION PROCESSES FOR ACS ON THE BASIS OF FUZZY CONTROL UNIT

Some basic notions of FL were presented e.g. in [10,11,12,13]. A fuzzy set A in a universe of discourse X is characterized by a membership function $\mu_A(x)$ which takes values in the interval [0,1], namely

$$\mu_A : X \rightarrow [0,1]. \tag{2}$$

Let A and B be fuzzy sets in X with membership functions $\mu_A(x)$ and $\mu_B(x)$. Theoretic operations of set intersection, union and complement for fuzzy sets are defined via their membership functions, more specifically, seen in Fig. 2.

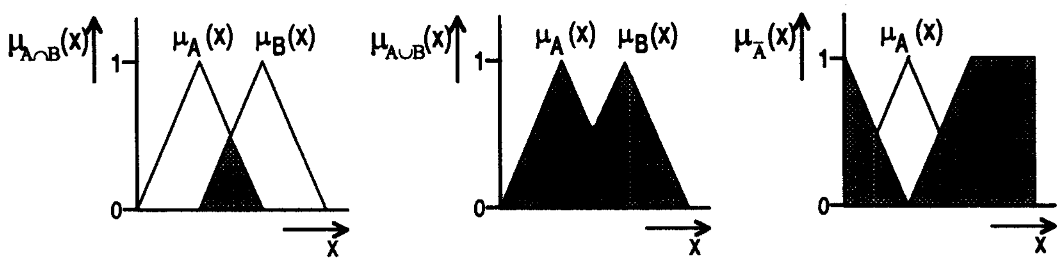

Fig. 2. Graphical interpretation of membership functions $\mu_{A\cap B}(x)$, $\mu_{A\cup B}(x)$ and $\mu_{\bar{A}}(x)$

Decision processes of ACS on the basis of FL can be realized by FCU [1,2,14] in Fig. 3. The output variable is determined on the basis of minimum values of input variables $d_{i,j}$ and $P_{i,j}$ in FCU. This output variable is M_j.

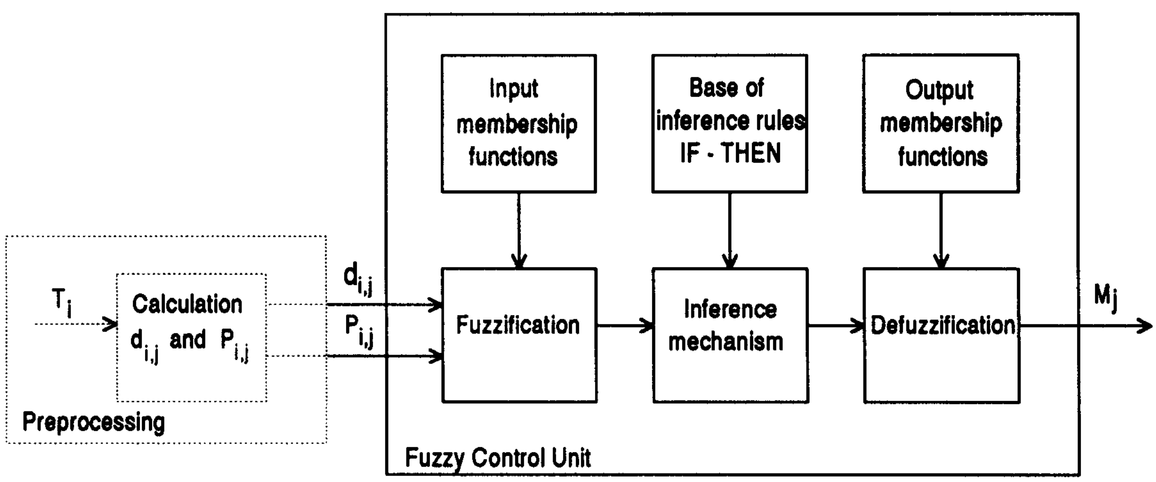

Fig. 3. The fuzzy control unit of decision processes of ACS

In order to analyze created FCU it is necessary to define [1,2,4,10]:
- number, form and scale of fuzzy sets of input- output variables;
- number and composition of inference rules;
- a defuzzification strategy.

There is no general method for the design of a form, number and parameters of input- output membership functions. A triangular, trapezoidal as well as other membership functions for the creation of FCU are used [11,12,14].

The definition of these variables of the created FCU is in Fig. 4, where $SM\_d_{i,j}$, $ME\_d_{i,j}$, $LA\_d_{i,j}$, $ZE\_P_{i,j}$, $MI\_P_{i,j}$, $GR\_P_{i,j}$, FIRST, SECOND, THIRD are fuzzy sets of input- output variables $d_{i,j}$, $P_{i,j}$ and M_j where SM is small, ME is medium, LA is large, ZE is zero, MI is middle and GR is great.

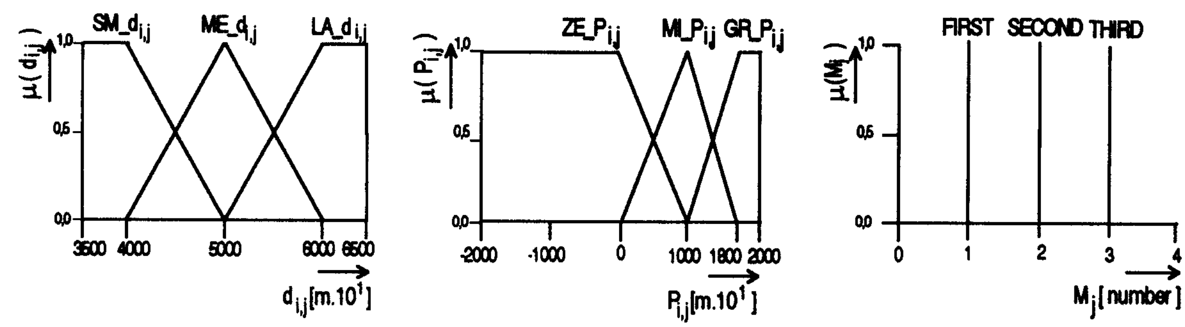

Fig. 4. Membership functions of input- output variables $d_{i,j}$, $P_{i,j}$ and M_j

Created inference rules are written in the form IF - THEN (IF antecedent-THEN consequent) [3,9,12,14,15]. The model of decision process of ACS has been analyzed. On the basis of this analysis 144 inference rules, have been created at devised which can be expressed in the following way:

Rule 1

IF $d_{1,1}$ is $SM\_d_{1,1}$ AND $d_{1,2}$ is $ME\_d_{1,2}$ AND $d_{1,3}$ is $ME\_d_{1,3}$ AND $P_{1,1}$ is $ZE\_P_{1,1}$ AND $P_{1,2}$ is $MI\_P_{1,2}$ AND $P_{1,3}$ is $GR\_P_{1,3}$
THEN M_j is FIRST.

Rule 2

IF $d_{1,1}$ is $SM\_d_{1,1}$ AND $d_{1,2}$ is $ME\_d_{1,2}$ AND $d_{1,3}$ is $ME\_d_{1,3}$ AND $P_{1,1}$ is $ZE\_P_{1,1}$ AND $P_{1,2}$ is $GR\_P_{1,2}$ AND $P_{1,3}$ is $MI\_P_{1,3}$
THEN M_j is FIRST.

Rule 3

IF $d_{1,1}$ is $SM\_d_{1,1}$ AND $d_{1,2}$ is $ME\_d_{1,2}$ AND $d_{1,3}$ is $ME\_d_{1,3}$ AND $P_{1,1}$ is $MI\_P_{1,1}$ AND $P_{1,2}$ is $ZE\_P_{1,2}$ AND $P_{1,3}$ is $GR\_P_{1,3}$
THEN M_j is FIRST.

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Rule 143
IF $d_{1,1}$ is SM_$d_{1,1}$ AND $d_{1,2}$ is SM_$d_{1,2}$ AND $d_{1,3}$ is LA_$d_{1,3}$ AND $P_{1,1}$ is GR_$P_{1,1}$ AND $P_{1,2}$ is ZE_$P_{1,2}$ AND $P_{1,3}$ is MI _$P_{1,3}$
THEN M_j je SECOND.

Rule 144
IF $d_{1,1}$ is SM_$d_{1,1}$ AND $d_{1,2}$ is SM_$d_{1,2}$ AND $d_{1,3}$ is LA_$d_{1,3}$ AND $P_{1,1}$ is GR_$P_{1,1}$ AND $P_{1,2}$ is MI_$P_{1,2}$ AND $P_{1,3}$ is ZE_$P_{1,3}$
THEN M_j is SECOND.

On the basis of analysis, as can be seen in [11], the best results of defuzzification are obtained with the method COG [7,11] (minimum time of the steady state achievment and least square error).

The fuzzy environment Knowledge Based Generator (KBG) [16,17] was used for modelling of FCU . Input variables are $d_{i,j}$ and $P_{i,j}$ for i=1, j=1,2,3. The output variable is M_j for the following values $d_{1,1}$=4100, $P_{1,1}$=300, $d_{1,2}$= 5400, $P_{1,2}$=900, $d_{1,3}$= 5900, $P_{1,3}$=1600 and their values of membership function $\mu(d_{i,j})$ and $\mu(P_{i,j})$ which are in Table 1.

Table 1. Membership function values $\mu(d_{i,j})$ and $\mu(P_{i,j})$ of input variables $d_{i,j}$ and $P_{i,j}$

		$\mu(d_{i,j})$			$\mu(P_{i,j})$		
		SM_$d_{i,j}$	ME_$d_{i,j}$	LA_$d_{i,j}$	ZE_$P_{i,j}$	MI_$P_{i,j}$	GR_$P_{i,j}$
$d_{i,j}$	$d_{1,1}$	0,91	0,09	0,0			
	$d_{1,2}$	0,0	0,61	0,39			
	$d_{1,3}$	0,0	0,11	0,89			
$P_{i,j}$	$P_{1,1}$				0,72	0,28	0,0
	$P_{1,2}$				0,12	0,88	0,0
	$P_{1,3}$				0,0	0,31	0,69

The calculation of the defuzzification value M_j according to the selected inference rules for chosen values in the model of decision processes of ACS is realized by COG method.

The graphical interpretations of the output of FCU in KBG are in Fig. 5a through 5d. The control curve expresses the dependence of the value of the output variable M_j from the selected value of input variables. The selected value is within the range from 4000 [m.10^1] to 6000 [m.10^1], and all other values of input variables are constant.

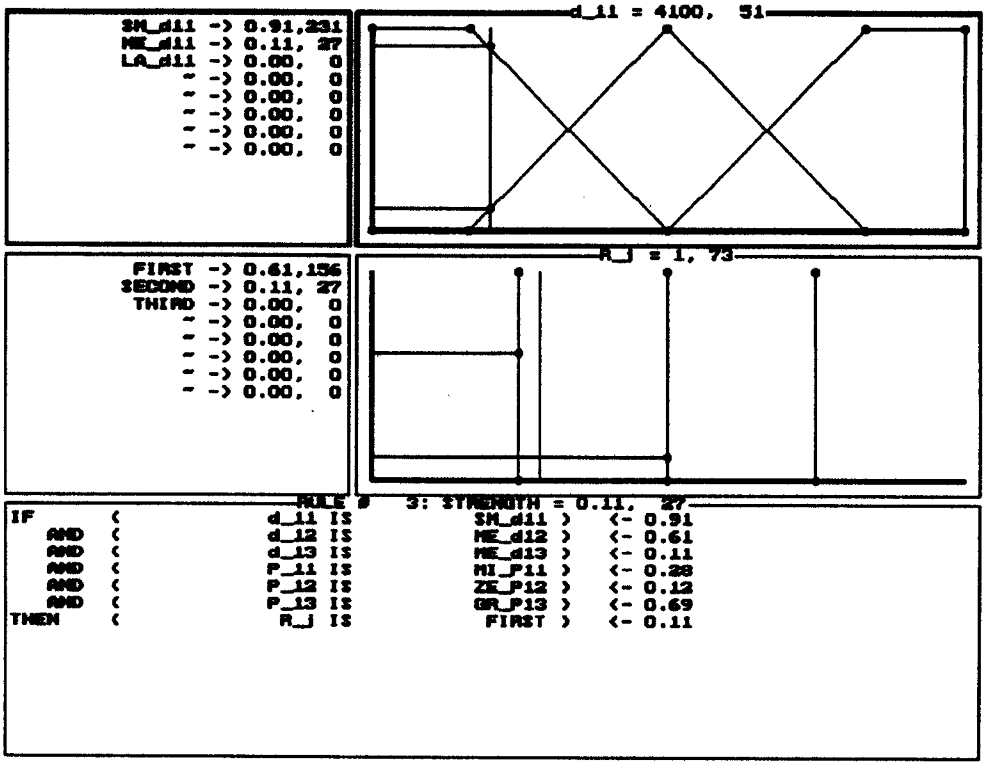

Fig. 5a. **The calculation of M_j on the basis $d_{1,1}$, $d_{1,2}$, $d_{1,3}$, $P_{1,1}$, $P_{1,2}$ and $P_{1,3}$**

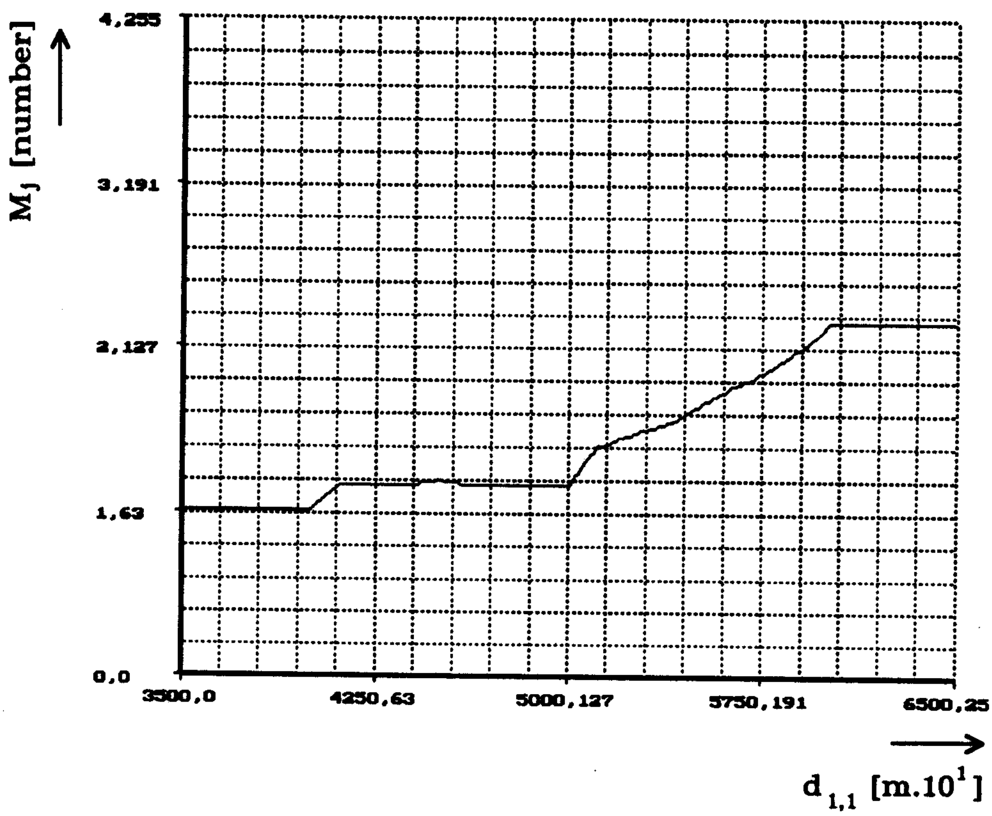

Fig. 5b. **The dependence of M_j on $d_{1,1}$, where $d_{1,2}$, $d_{1,3}$, $P_{1,1}$, $P_{1,2}$, $P_{1,3}$ are constant**

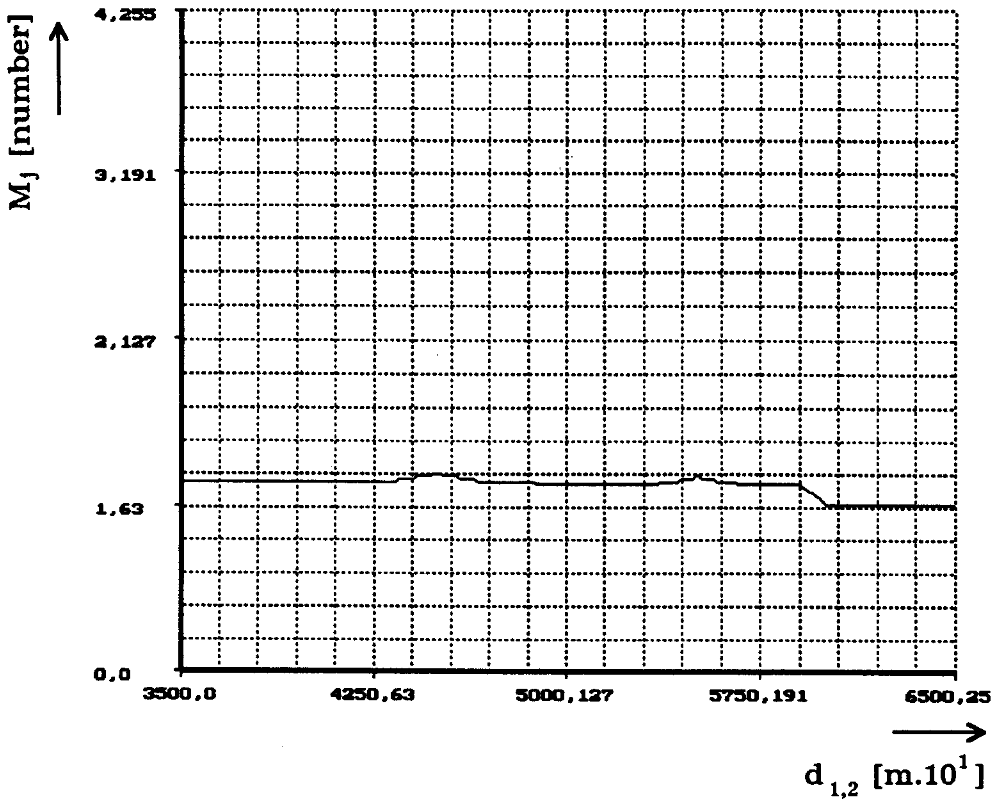

Fig. 5c. The dependence of M_j on $d_{1,2}$, where $d_{1,1}$, $d_{1,3}$, $P_{1,1}$, $P_{1,2}$, $P_{1,3}$ are constant

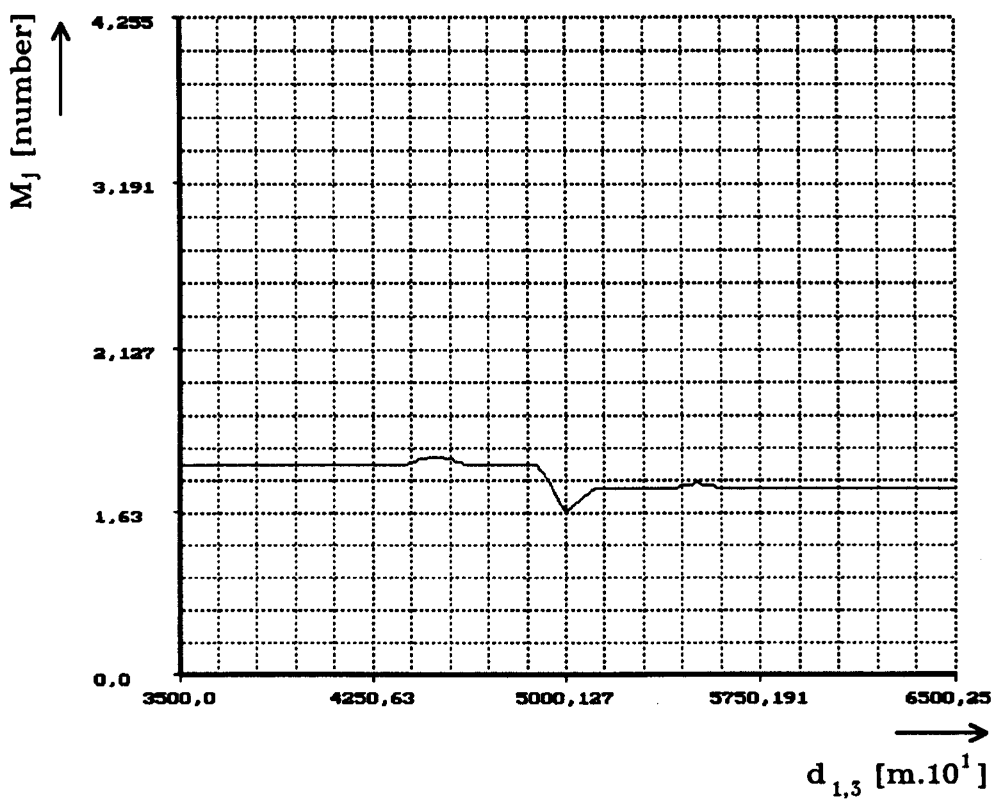

Fig. 5d. The dependence of M_j on $d_{1,3}$, where $d_{1,1}$, $d_{1,2}$, $P_{1,1}$, $P_{1,2}$, $P_{1,3}$ are constant

In Fig. 5a the calculated output value of means of combat M_j is shown. In Fig. 5b the dependence of the assigned means of combat M_j is shown with the change of value $d_{1,1}$ in the following way:

- the first means of combat M_j is given for values $d_{1,1} \in <4000,5000>$ with unevenness for values $d_{1,1} \in <4400,4550>$, where fuzzy sets $SM\_d_{1,1}$ and $ME\_d_{1,1}$ have membership function value $\mu(d_{1,1})$ equal 0,5;
- for values $d_{1,1} \in (5000,6000>$ there is a change in assigning of the first to the second means of combat M_j.

In Fig. 5c the dependence of the assignment the first means of combat M_j is shown with the change of value $d_{1,2}$ in the whole interval with unevenness for the values $d_{1,2} \in <4400, 4550>$ and $d_{1,2} \in <5450,5600>$, where fuzzy sets $SM\_d_{1,1}$, and $ME\_d_{1,1}$ and $LA\_d_{1,2}$ have membership function value $\mu(d_{1,2})$ equal 0,5.

In Fig. 5d the dependence of the assigned first means of combat M_j is shown for the change of value $d_{1,3}$ in the whole interval with unevenness for values $d_{1,3} \in <4400, 4550>$ and $d_{1,3} \in <5450,5600>$, where fuzzy sets $SM\_d_{1,3}$ and $ME\_d_{1,3}$ and $LA\_d_{1,3}$ have membership function value $\mu(d_{1,3})$ equal 0,5.

4. CONCLUSION

The using of FL represents an effective method for the synthesis and analysis of decision processes of ACS. As an original contribution we consider the model design of decision processes of ACS. On the basis of the model the autors proposed the FCU. No exact method exists which could determine the number of inference rules for FCU. The heuristic approach is used for design of the inference rule base. There is no exact method exist for determination of the number of inference rules. Thus, it is necessary to work with other methods for synthesis and analysis of decision processes of ACS, one of them being the programming language fuzzy PROLOG.

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