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OPTIMUM NOMINAL METHOD MODIFICATION AT THE MANAGEMENT OF MOVING OBJECTS UNDER UNCERTAINTY

Finaev V. I., Ignatyev V. V., Shestova E. A., Spiridonov O. B., Zargaryan J. A. and Zargaryan E. V.
Southern Federal University, Rostov-on-Don, Bolshaya Sadovaya Str, Russia
E-Mail: iskobersi@mail.ru

ABSTRACT

The articleis devoted to the development of models and information support for the search of the input parameters providing effective functioning of a moving object in the incompleteness data conditions. The problem of optimization is solved by theapplication of fuzzy intervals and variables. Parameters of moving objects of autonomous navigation and function of optimization are considered in the form of linguistic and fuzzy variables. Experts set functions of the accessory of fuzzy variables. The concept of the function of the accessory of deviations from the set face value of input parameter is defined. Modification of the method of the optimum of face value is considered at management of moving objects in the conditions of uncertainty. The algorithm and information support is developed for search of the fuzzy maximum of the function of the productivity of autonomous navigation at management of moving objects. The description of work with information support is provided.

Keywords: moving objects, decision-making, optimization, uncertainty, fuzzy interval, optimum nominal, control systems, information support.

1. INTRODUCTION

A searchfor the greatest value of the indicator of overall performance of moving object is connected with the definition of a subset of input parameters [1 3]. If managing parameters belong to this subset, best values of the selected criteria of work for moving object are provided. The problem of search of the greatest function value of productivity of autonomous navigation is reduced to the problem of search of a subset of input parameters. The prototype for the solution of this task has taken method of "face value optimum" the offered Svecharnik D.V. [4] and Zdora V.V developed in works Gorelova G.V., Abramova O.V.

The object is defined *by* $X=\{x_1, x_2,..., x_m\}\}$ input and $Y=\{y_1, y_2,..., y_n\}$ output parameters. At application of classical optimization methods [5] it is necessary to set optimality criterion on the set of variables $Y=\{y_1, y_2,..., y_n\}$. in the beginning. This optimality criterion depends on set of variables $X=\{x_1, x_2,...,x_m\}$. For search of the optimum law of management, it is necessary to find analytical dependence between variables of vectors *of Y and X* in optimality criterion, that is not always possible.

In actual practice task parameters, as a rule, are random variables. At stochastic communication between parameters, X and Y apply methods of statistical optimization and planning method of experimental design [5, 6]. Application of these methods is not always admissible in actual practice since, the administrative process is affected by big perturbations, or it is impossible to organize active experiment [7].

The method of "optimum nominal" allows making the control algorithm providing achievement of maximum efficiency of functioning of moving object [8, 9]. "Face value" call the value of task of conducting process the control device. Real values of the process have deviations from face value. Processing of supervision over real process allows setting distribution laws of deviations from the set face value. Also, the limit admission on deviations is considered.

Difference of proposed solution optimization problem dynamic process parameters in the incompleteness data conditions is as follows. Objects parameters and optimization function are considered in the form of linguistic and fuzzy variables [7, 10, 11]. Experts set functions of the accessory of fuzzy variables. The task solution is connected with the definition of the nominal displacement efficiency function of autonomous navigation that will give the greatest value of fuzzy efficiency of object functioning [12, 13]

2. MODIFICATION OF THE OPTIMUM NOMINAL METHOD WITH INCOMPLETE DATA

Interpretation of optimum nominal method, we will consider for position and trajectory management systems [1] moving objects in the uncertainty conditions. Let's consider that distribution function of the effectiveness of autonomous navigation control systems *of a j*-moving object from the set face value is defined by the normal law of frequency curve *of* $f(x)$. Illustration selecting the optimum performance of the functions of a j-moving object is shown in Figure-1.

In Figure-1 section 1 productivity deviations distribution *j* of moving object from the set face value; section 2- productivity distribution *j* of moving object at

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which the value of productivity function reaches the maximum value [5,14].

I bands (*i=1...., s)* correspond to different values functioning efficiency (objective execution efficiency) of autonomous navigation of moving objects. The Price of each band*of* b_i. Efficiency function formula will determine$\varphi(\mu_1,\ldots,\mu_m)$

$$\varphi = \sum_{i=1}^{s} b_i \int_{x_{in}}^{x_{ik}} f(x)dx \,, \tag{1}$$

where: $\int_{x_{in}}^{x_{ik}} f(x)dx$ – the probability of a hit of random variable *x* in i band; x_{in} and x_{ik} - coordinates has also begun the end *of i-y* of the band.

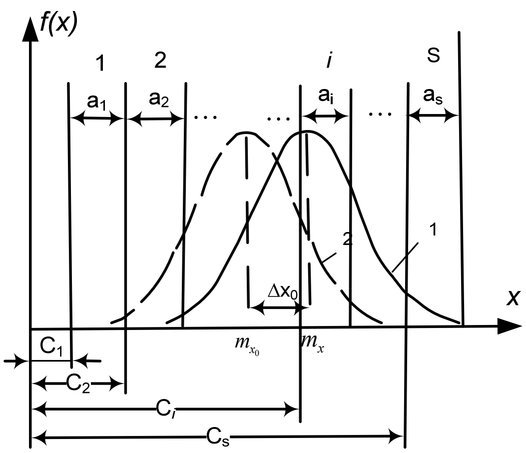

Figure-1. Choice of optimum nominal of productivity function *of j-go* of moving object.

It is necessary to define arrangements of distribution curve *of f (x)* with mathematical expectation $\mu_{of\ x0}$, at which efficiency function value $\varphi(\mu_1,\ldots,\ \mu_m)$ reaches the maximum value.Formula determines value of optimum function of efficiency

$$\varphi_0(\Delta x_0) = \sum_{i=1}^{s} b_i \int_{x_{in}+\Delta x_0}^{x_{ik}+\Delta x_0} f(x)dx \tag{2}$$

where Δx_0 – the value of optimal shift curve distribution density *of f (x)* from the initial position, as shown in Figure-1. It is obvious that$m_{x0}=m_x-\Delta x_0$.

For determination of value Δx_0 it is necessary to take differential of the equation (1) on Δx and to equate it to zero:

$$\frac{\partial\varphi}{\partial(\Delta x)} = \frac{\partial\varphi}{\partial(\Delta x)}\left[\sum_{i=1}^{s} b_i \int_{x_{in}+\Delta x_0}^{x_{ik}+\Delta x_0} f(x)dx\right] = 0 \tag{3}$$

The optimum status of moving object will be defined by function value of efficiency of functioning that meets condition:

$$\sum_{i=1}^{s} b_i \left[f\left(x_{ik}+\Delta x\right) - f\left(x_{in}+\Delta x\right)\right] = 0 \tag{4}$$

At the solution of an optimizing task consider the width *of i* of a strip *of* a_i and distance *of i* strip from the chosen c_i reference mark. Function efficiency of functioning of system of autonomous navigation $\varphi(\mu_1,\ldots,\mu_m)$ we will determine by formula

$$\varphi(\Delta x) = \sum_{i=1}^{s} b_i \int_{\Delta x+c_i}^{\Delta x+c_i+a_i} f(x)dx \tag{5}$$

The optimum status of moving object will be defined by function value of efficiency of functioning that meets condition

$$\sum_{i=1}^{s} b_i \left[f\left(x_{ik}+c_i+\Delta x\right) - f\left(\Delta x + c_i\right)\right] = 0\,. \tag{6}$$

At known coefficients *of* b_i, a_i, c_i, x_{in} and x_{ik},, and the known distribution law f *(x)* in the equations (4), (6) it is possible to determine required value Δx_0.

At application of the method of the optimum of face value in the statement of work [4], it is considered known frequency curve *of* $f(x_i)$ of deviations for each x_i parameter from the set face value. This hypothesis is disputable. It is confirmation requires statistical selection. The power of choice is defined proceeding from the given accuracy of assessment. It is rather difficult to prove accuracy. Thus, the optimum nominal method error determined by the doubtful choice of frequency curve *of* $f(x_i)$. Also, there are no reliable analytical methods for searching the extremes of large dimension functions.

In this article, it is offered to solve the optimization problem in the conditions of incompleteness of essential data on the application of fuzzy intervals and variables.

We will determine input and output parameters of moving an object in the form of fuzzy intervals [11, 14]. Each component x_i, $i=\overline{1,m}$ vector of input parameters, we will define in the form of set $x_i = <\underline{m}_i, \overline{m}_i, \alpha_i, \beta_i>$, where

ARPN Journal of Engineering and Applied Sciences

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$\underline{m}_i$ and $\overline{m}_i$ the lower and upper modal α_i and β_i the left and right coefficient of illegibility for the parameter x_i, $i=\overline{1,m}$. A similar definition can be applied and to task component of the vector of output parameters of the control object.

Instead of frequency curve *of* $f(x_i)$ we will enter the concept of the function of the accessory of deviations from the set x_i parameter face value. Also in the form of indistinct intervals also coefficients *of* b_i, a_i, c_i,x_{in} can be set. As a result, we will receive the modified face value optimum method in fuzzy terms. This modified method of the optimum of face value can be considered, one-dimensional optimization problem. In Figure-2 the choice of fuzzy optimum nominal of the function of the efficiency of functioning *of j* of a mobile object is shown.

Optimum nominalmethodmodification is illustrated by example. Is defined by experts in the form of function of the accessory of deviation from rated value of efficiency of functioning of moving object. On measurement interval of this value set fuzzy segments (bands) and values of the prices in each segment.

Modification of the method of optimum par with fuzzy parameters allows defining a displacement of the nominal value, which will give the greatest value of fuzzy system moving object performance control.

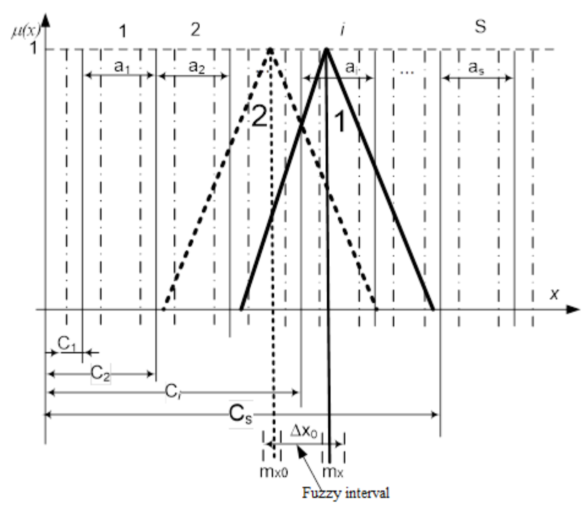

Figure-2. Choice of fuzzy optimum nominal of productivity function *j-th* of moving object.

Let's review an example of the one-dimensional optimization problem function effectiveness of the autonomous navigation system for position and trajectory control systems moving objects. Experts have defined the fuzzy function of accessory $\tilde{f} =< \underline{m}_f, \overline{m}_f, \alpha, \beta >$ deviations from the set nominal efficiency of functioning for the existing management system mobile object with the set parameters $\underline{m}_f, \overline{m}_f, \alpha, \beta$.

Let the control system demands productivity coefficient 0, 90, 05±. Minimum possible value of productivity makes x_{min}=0, 6 (x_{min}=x_{1n}) and the greatest possible x_{max}=1 (x_{max}=x_{1k}). The number of bands *of s=4*. Coordinates and the price of bands are set in fuzzy look. The type of task of coordinates of bands and the prices are givenin Table-1.

Table-1. Fuzzy intervals specifying the coordinates of the bands and prices.

Number of bands	**1**	**2**	**3**	**4**
Fuzzy price of band	$\tilde{b}_1$	$\tilde{b}_2$	$\tilde{b}_3$	$\tilde{b}_4$
Fuzzy lower coordinate of band	$\tilde{x}_{1min}$	$\tilde{x}_{2min}$	$\tilde{x}_{3min}$	$\tilde{x}_{4min}$
Fuzzy upper coordinate of band	$\tilde{x}_{1max}$	$\tilde{x}_{2max}$	$\tilde{x}_{3max}$	$\tilde{x}_{4max}$

Let's determine fuzzy lower coordinates of bands as fuzzy numbers $\tilde{x}_{imin} =< \overline{m}_{imin}, \alpha_{imin}, \beta_{imin} >,\ i=\overline{1,4}$ and upper coordinates of bands as fuzzy numbers $\tilde{x}_{imax} =< \overline{m}_{imax}, \alpha_{imax}, \beta_{imax} >,\ i=\overline{1,4}$.

Let $\tilde{x}_{1min} =< 0,6; 0; 0,02 >$,

$\tilde{x}_{2min} =< 0,7; 0,01; 0,03 >$,

$\tilde{x}_{3min} =< 0,8; 0,04; 0,05 >$

$\tilde{x}_{4min} =< 0,9; 0,01; 0,04 >$,

$\tilde{x}_{1maa} =< 0,65; 0,01; 0,01 >$,

$\tilde{x}_{2maa} =< 0,75; 0,02; 0,03 >$,

$\tilde{x}_{3maa} =< 0,85; 0,02; 0,03 >$,

$\tilde{x}_{4maa} =< 1; 0,1; 0 >$ are defined by experts.

The fuzzy prices of bands are set by fuzzy numbers $\tilde{b}_i =< \overline{m}_i, \alpha_i, \beta_i >,\ i=\overline{1,4}$:

$\tilde{b}_1 =< -20,4,3 >$, $\tilde{b}_2 =< 25,5,6 >$, $\tilde{b}_3 =< 15,3,3 >$, $\tilde{b}_4 =< -17,3,4 >$. The prices $\tilde{b}_1 =< -20,4,3 >$ and $\tilde{b}_4 =< -17,3,4 >$ are negative since finding of function in the first and second bands yields "losses" to control system.

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ARPN Journal of Engineering and Applied Sciences

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For calculation of fuzzy value $\Delta\tilde{x}_0$ by analogy with formula (4) we will receive the equation for function of accessory of the fuzzy variable "efficiency of functioning" characterizing optimum status of the considered object:

$$\begin{aligned}&\tilde{b}_1\tilde{\times}\left[(\tilde{f}(\tilde{x}_{1k}\tilde{+}\Delta\tilde{x})-(\tilde{f}(\tilde{x}_{1n}\tilde{+}\Delta\tilde{x})\right]\tilde{+}\\&\tilde{+}\tilde{b}_2\tilde{\times}\left[(\tilde{f}(\tilde{x}_{2k}\tilde{+}\Delta\tilde{x})-(\tilde{f}(\tilde{x}_{2n}\tilde{+}\Delta\tilde{x})\right]\tilde{+}\\&\tilde{+}\tilde{b}_2\tilde{\times}\left[(\tilde{f}(\tilde{x}_{2k}\tilde{+}\Delta\tilde{x})-(\tilde{f}(\tilde{x}_{2n}\tilde{+}\Delta\tilde{x})\right]\tilde{+}\\&\tilde{+}\tilde{b}_3\tilde{\times}\left[(\tilde{f}(\tilde{x}_{3k}\tilde{+}\Delta\tilde{x})-(\tilde{f}(\tilde{x}_{3n}\tilde{+}\Delta\tilde{x})\right]\tilde{+}\\&\tilde{+}\tilde{b}_3\tilde{\times}\left[(\tilde{f}(\tilde{x}_{3k}\tilde{+}\Delta\tilde{x})-(\tilde{f}(\tilde{x}_{3n}\tilde{+}\Delta\tilde{x})\right]\tilde{+}\\&\tilde{+}\tilde{b}_4\tilde{\times}\left[(\tilde{f}(\tilde{x}_{4k}\tilde{+}\Delta\tilde{x})-(\tilde{f}(\tilde{x}_{4n}\tilde{+}\Delta\tilde{x})\right]\cong 0\end{aligned} \quad (7)$$

where $\tilde{\times}$ - the fuzzy operation of multiplication, $\tilde{+}$ - fuzzy operation of summing.

Basic data for the considered task are shown in Figure-3.

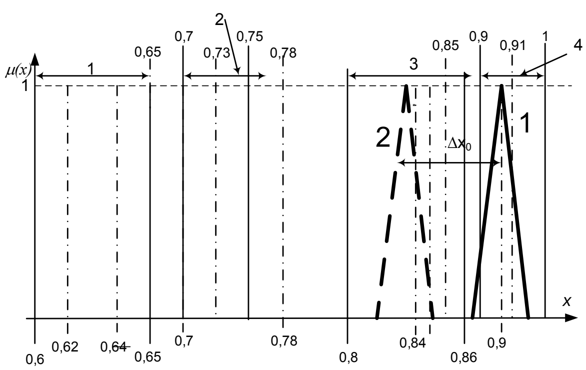

Figure-3. Choice illustration of fuzzy optimum nominal of the function of the accessory of the fuzzy variable "efficiency of functioning.

Search of fuzzy optimum nominal will be defined by formula

$$\sum_{i=1}^{s}\tilde{b}_i\tilde{\times}\left[(\tilde{f}(\tilde{x}_{ik}\tilde{+}\Delta\tilde{x}_0)-(\tilde{f}(\tilde{x}_{in}\tilde{+}\Delta\tilde{x}_0)\right]\cong 0 \quad (8)$$

where $\Delta\tilde{x}_0$ - required a fuzzy shift of fuzzy function of accessory $\tilde{f}=<\underline{m}_f,\overline{m}_f,\alpha,\beta>$.

The solution of the equation (8) is the fuzzy interval $\Delta\tilde{x}_0$. It means that at shift fuzzy function of accessory $\tilde{f}=<\underline{m}_f,\overline{m}_f,\alpha,\beta>$ deviations from the set nominal of function of efficiency of functioning of control system moving objects on fuzzy value $\Delta\tilde{x}_0$ (curve 2 in Figure-3) maximum efficiency of administrative process is reached.

3. THE OPTIMUM NOMINAL METHODALGORITHMIZATION WITH FUZZY PARAMETERS

The search algorithm of a fuzzy maximum of the function of the efficiency of functioning for one fuzzy function of the accessory of deviations from the set nominal is shown in Figure-4.

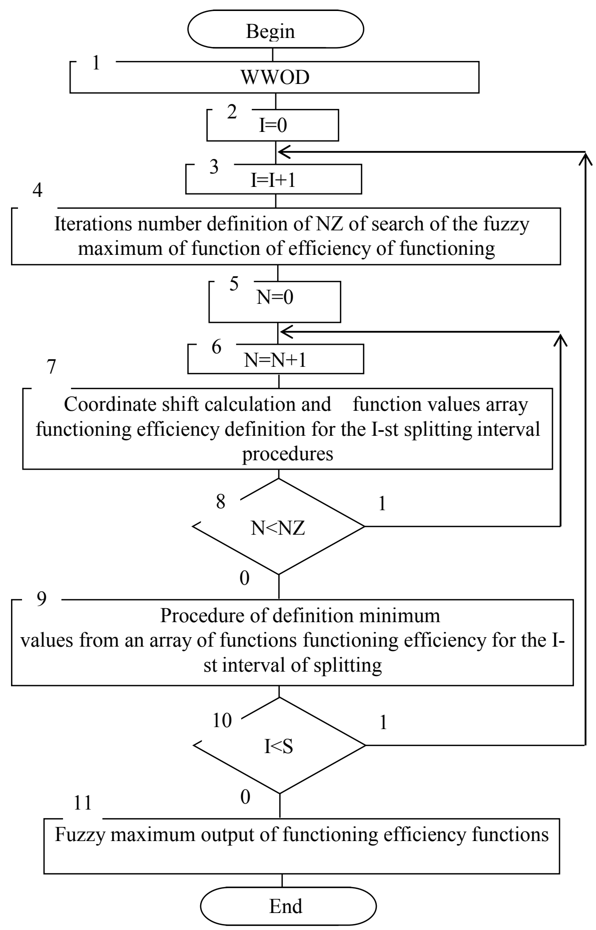

Figure-4. Search algorithm of fuzzy maximum of function of efficiency of functioning.

In interactive mode basic data are entered during the WWOD procedure work:

- the number of bands of splitting s of a basic set *of X*is defined by the identifier S;

- on basic great number of X splitting parameter x in the form of indistinct points is set $\widetilde{x}_i,\ i=\overline{0,s}$ (multidimensional array of X [I, LKI, MXI, PKI], where I - the identifier of number of fuzzy point on band, LKI of value of the left coefficients of illegibility; MXI – modal value, PKI of value of the right coefficients of fuzzy point $\widetilde{x}_i$);
- for each band of splitting the fuzzy prices of bands are set $\widetilde{b}_j,\ j=\overline{1,s}$ (at fuzzy task of the prices multidimensional array of B [J, LKJ, MCJ, PKJ], where J identifier of index of band $j=\overline{1,s}$, LKJ of value of the left coefficients of illegibility; MCJ – modal value, PKJ of value of the right coefficients of illegibility of the fuzzy price $\widetilde{b}_j$; in case of accurate task of the price of band the array of the prices has B[J] appearance);
- precision value ε fuzzy definition of the maximum of the efficiency of the defined identifier E;
- $\widetilde{f}=<\underline{m}_f,\overline{m}_f,\alpha,\beta>$ -task of fuzzy function of accessory of deviations from the nominal value (array of F[LKF, MNF, MNF, PKF], where LKF of value of the left coefficient of illegibility; MNF – the lower modal value, MNF – upper modal value, PKF value of the right coefficient of illegibility of function $\widetilde{f}=<\underline{m}_f,\overline{m}_f,\alpha,\beta>$).

Blocks 2, 3 and 10 are intended for the organization of cycle for the I=1, 2,…, S – to number of bands of a fuzzy splitting basic set *of X*.

Procedure (block 4) for determining the number of iterations of NZ allows to define step for calculation $\Delta\tilde{x}$ function values of efficiency functioning. Formula will determine the number of NZ iterations

$$NZ=\frac{MX(I+1)-MXI}{E} \tag{9}$$

where MX(I+1) – modal value of fuzzy point $\widetilde{x}_{i+1}$; MXI - modal value of fuzzy point $\widetilde{x}_i,\ i=\overline{0,s-1}$.

Blocks 5, 6 and 8 are intended for the organization of cycle for the N=1,2,…, NZ. In the procedure for calculating the offset coordinates given by the value of the argument a step function of the efficiency of functioning, so that

$$\Delta\tilde{x}=\tilde{x}_i+N\times E \tag{10}$$

In the procedure of definition of array cells of function values of the efficiency of functioning (block 7), there is filling of an array of F [I, N] for the I-st interval of splitting. Definition of array cells happens to formula

$$F[I,N]=\sum_{i=1}^{s}\widetilde{b}_i\,\widetilde{\times}\begin{bmatrix}(\widetilde{f}(\widetilde{x}_{ik}\,\widetilde{\mp}\,\Delta\widetilde{x})-\\-(\widetilde{f}(\widetilde{x}_{in}\,\widetilde{\mp}\,\Delta\widetilde{x})\end{bmatrix}\cong 0 \tag{11}$$

In the procedure of determination of the minimum value (block 9) that value is defined $\Delta\tilde{x}=\tilde{x}_i+N\times E$ by F array [I, N] values of functions of productivity for the I-st interval of splitting. To value $\Delta\tilde{x}$ there corresponds the greatest array cell and this array cell and value $\Delta\tilde{x}=\tilde{x}_i+N\times E$ I is remembered in FM array [X].

In fuzzy maximum output procedure functioning efficiency function (block 11) the maximum element from FM array is defined [I, X] and the decision of rather a fuzzy nominal is made $\Delta\tilde{x}_0=\tilde{x}_i+N\times E$, to which there corresponds the fuzzy maximum of function of efficiency of functioning.

Information support

The main menu of information support [14, 15, 19] provides rapid access to settings of system and results of execution of the program. After the start of the program of the monitor, the starting windowis displayed. In this window, it is necessary to enter general options of the system. For example, if the basic great number of X is defined on interval [10; 120], it is necessary to the “From” and “To” fields under text of "Base set X", respectively, to write values 10 and 120. In the same way, the fuzzy interval of the price of S is defined. In the reviewed S∈ [20; 70].

Also, it is necessary to define the quantity of fuzzy bands of the price *of i*. It is necessary to enter a value in the field of "Number of fuzzy price bands" in *i=5*. Also, we execute input of setup of the accuracy of the output of result of the solution. If, for example, receiving a result with *e=0, 1* accuracy is required, it is necessary to write this value of accuracy in the field of "Decision accuracy". For saving of settings, it is necessary to click "Accept".

ARPN Journal of Engineering and Applied Sciences

The input of values in the General settings window is shown in Figure-5.

Then it is necessary to make settings for face value. For this purpose, it is necessary to open tree of "Settings" in the main menu and to select the subsection "Nominal". The window of setup nominal is shown in Figure-6. Settings of nominal are made by capture and movement of three points of function or task of modal value and illegibility coefficient.

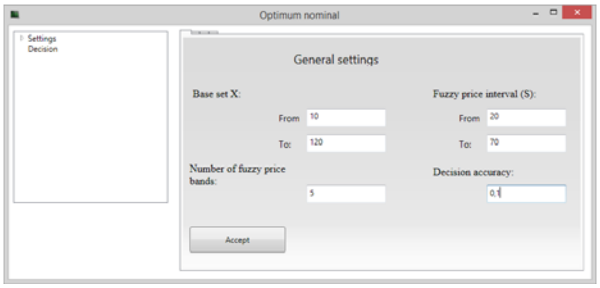

Figure-5. The window "General Settings."

For example, we will define fuzzy *M= (α,m, β) = (10, 60, 10)* interval*, α =β,* where *α* – the right illegibility coefficient, *m* - fuzzy interval modal value, *β* – the left illegibility coefficient. For this purpose, we will enter into the Fuzziness coefficient and Modal value fields, values *10 and 60* respectively.

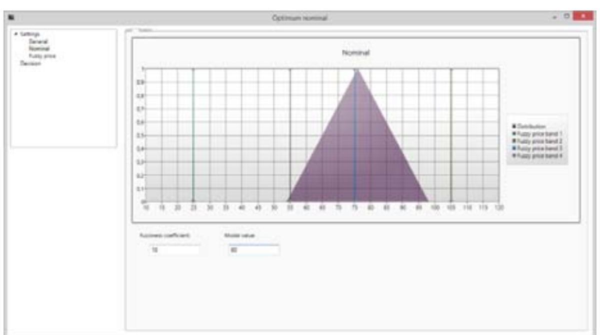

Figure-6. Nominal settings window.

Fuzzy bands prices settings are also made by capture and selected fuzzy band movement. In band example have coordinates, respectively, to number of band [10; 25], [25; 55], [55, 75], [75; 105], [105,120]. Further, we determine the fuzzy price. For this purpose, it is necessary to select the subsection "Fuzzy price" from the main menu. It is necessary to set fuzzy function price type, manipulating the left mouse button in functions tops point's neighbourhoods and dragging them to the necessary position. In Figure-7 the fuzzy price task example is given.

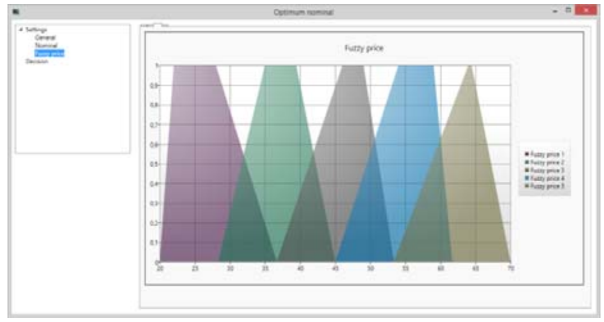

Figure-7. Fuzzy price task example.

At these stage system parameters, setup is ended. It is necessary for receiving search the optimum nominal result in the program main menu to select the section "Decision", and then to press the Start button.

The output rather given distribution function and also shift nominal numerical value output in the field of "Conclusion" will be the program execution result. The program runtime result is shown in Figure-8.

Optimum nominal method information support with fuzzy parameters can be implemented with remote access [8, 15-17, 18-21] on the Internet.

This solution can be applied to the case of one, two local management system criteria. However, if number of local criteria more than two appear difficulties both with parameters formalization, and because of problem definition and its solution complexity.

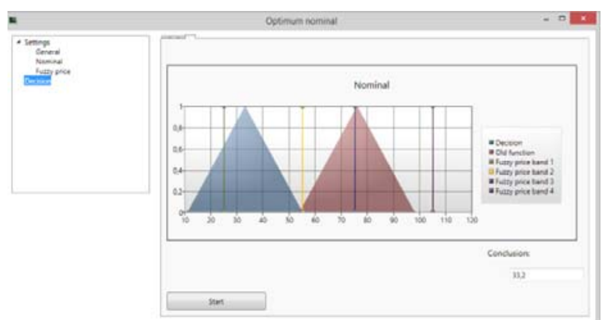

Figure-8. Program execution result.

CONCLUSIONS

The mobile object efficiency functioning optimization problem solution differs in that on the basis of the nominal optimum method in the data search incompleteness conditions of verbally certain input variables is carried out. These input variables provide defined object functioning efficiency maximum values creation achievement in the deviation accessory function from the nominal value.

Mobile objects give the optimum nominal method fuzzy modification illustration on the example of management system efficiency functioning one-dimensional problem optimization.

The system management efficiency functioning fuzzy maximum search algorithm is developed by mobile objects and information support for a nominal optimum method with fuzzy parameters. The information support description on the management system optimization parameters example in the basic data incompleteness conditions is provided.

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REFERENCES

[1] Pshikhopov V.K., Medvedev M.Yu., Gurenko B.V. 2014. Homing and Docking Autopilot Design for Autonomous Underwater Vehicle. Applied Mechanics and Materials. pp. 490-491.

[2] Zargaryan Yu, I. Shapovalov, V. Soloviev, V. Finaev, D. Beloglazov E. Kosenko. 2014. Influence of internal and external factors on a controlled quadrotor flight. International journal of mathematical models and methods in applied sciences Vol. 8, ISSN: 1998-0140. pp. 498-504.

[3] Zargaryan Yu, I. Kobersy, V. Finaev, D. Beloglazov, I. Shapovalov, V. Soloviev. 2014. Research on the intelligent adaptive hybrid control system for an autonomous mobile robot. Advances in Engineering Mechanics and Materials. Santorini Island, Greece. ISBN: 978-1-61804-241-5. pp. 211-216

[4] Svecharnik D.V. 1957. A Task about Nominal Optimum. Works of Machine Science Institute, M., Publisher: AS of the USSR. 10: 78-94.

[5] Antoniou A., Lu W.-S. 2007. Practical Optimization. Algorithms and Engineering Applications. Publisher: Springer. p. 675.

[6] Altannar Chinchuluun, Panos M. Pardalos, Rentsen Enkhbat, Ider Tseveendorj. 2010. Optimization and Optimal Control: Theory and Applications. Publisher: Springer-Verlag New York, LLC. p. 524.

[7] Zargaryan Yu, I. Shapovalov, V. Soloviev, V. Finaev, D. Beloglazov, E. Kosenko. 2014. Research of the controlled flight dynamics based on the full and simplified quadrotor models. Advances in Engineering Mechanics and Materials. Santorini Island, Greece. ISBN: 978-1-61804-241-5. pp. 17-22.

[8] Finaev V.I., Zargaryan Yu. 2013. Multicriterion Decision Making in Case of Incomplete Source Data. World Applied Sciences Journal. 23 (9): 1253-1261. ISSN 1818-4952. ©IDOSI Publications, 2013 DOI: 0.5829/idosi.wasj.2013.23.09.13140.

[9] Zargaryan Yu. A. and V.I. Finaev. 2011. Optimization method of dynamic process parameters in conditions of data incompleteness. Herald of RGUPS, Rostov-on-Don. 3(39): 74-78.

[10] Mamdani E.H. 1977. Application of fuzzy logic to approximate reasoning using linguistic synthesis / IEEE Transactions on Computers. 26(12): 1182-1191.

[11] ДюбуаД., Прад. А. 1990. Теориявозможностей: Пер. сфранцузскогоВ.Б. Тарасова /ПодредакциейС.А. Орловского. М.: РадиоиСвязь. p. 288.

[12] Ivan V. Sergienko. 2012. Methods of Optimization and Systems Analysis for Problems of Transcomputational Complexity. Springer-Verlag New York, LLC. p. 280.

[13] Zargaryan Yu, E.V. Zargaryan, I.V. Pushnina, V.I. Finaev, E.A. Shestova. 2014. Testing Knowledge on The Basis of Stochastic Analysis. International Journal of Applied Engineering Research ISSN 0973-4562, 9(22): 16403-16412.

[14] Timothy J. Ross. 2012. Fuzzy Logic with Engineering Applications. Wiley-Blackwell (an imprint of John Wiley and Sons Ltd). p. 606.

[15] Agarwal V.V. 2012.Beginning C# 5.0 Databases. 2nd edition. Apress. p. 440.

[16] Richard Banks. 2012. Visual Studio 2012 Cookbook. Packt Publishing Ltd. p. 272

[17] Andrew Troelsen. 2012. Pro C# 5.0 and the .Net 4.5 Framework. Publisher: Apress. p. 1487.

[18] Finaev Valery, I., Beloglazov Denis A., Shapovalov Igor O., Kosenko EvgenyY.a and Kobersy Iskandar, S. 2015. Evolutionary algorithm for intelligent hybrid system training. ARPN Journal of Engineering and Applied Sciences. 10(6): 2386-2391.

[19] Beloglazov Denis, A., Finaev Valery, I., Zargarjan Jury, A., Soloviev Victor, V., KosenkoEvgeny, Y.,

Kobersy Iskandar S. 2015. Efficiency of genetic algorithms in intelligent hybrid control systems. ARPN Journal of Engineering and Applied Sciences. 10(6): 2488-2495.

[20] Kobersy I.S., Ignatev V.V., Beloglazov D.A., Kramarenko E.R. 2014. An intelligent navigator with the control of the car technical condition. ARPN Journal of Engineering and Applied Sciences. 9(7): 1094-1098.

[21] Finaev V., Kobersy I., Beloglazov D., Shapovalov I., Kosenko E., Soloviev V. 2015. Design of the neuro-like learning control system for a vehicle.WSEAS TransactionsonSystemsandControl. 10: 328-334.