Entropy Modeling of Optimal Intelligence Development in Regards with the Air Transport Operation

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Abstract

The paper is devoted to the entropy computer modeling of optimal intelligence development in regards with the air transport operation. The subjective analysis theory of the active systems is used as a framework for theoretical elaborations. The contemplations are based upon the subjective entropy paradigm. Several solutions are obtained for a few special cases considered. Conditional optimization of the subjective individuals' preferences functions entropy in conjunction with the proposed hybrid combined relative pseudo-entropy function happened to be helpful in determining the relative certainty/uncertainty degree concerning prevailing/dominating subjective preferences functions. Illustrative examples simulations are performed. Necessary diagrams are plotted.

Keywords

Entropy, preferences, operation, air transport, optimization, intelligence, management, simulation, objective functional.

1. Introduction

Rational methods of the air transportation management systems functioning in the operation are important. Aircraft maintenance and repair [1, 2] procedures are aimed at the aeronautical engineering reliability support, as well as at the decrease of the risks and negative consequences of the aircraft systems, systems' components, and systems' elements failures [3, 4].

The models of intelligence used at the air transportation management systems functioning simulation should take into account the elements of the aviation transportation systems activities usefulness [5, 6].

The uncertainty degree could be evaluated in the framework of the entropy maximum theory terms as in [7 – 9]. The trend of the entropy research in modern science is very popular altogether [10]. Assessing economical parameters and terms [11], it is logically to combine the issues of the publications of [7 – 11] into the subjective analysis theory [12] that has been successfully developed by Professor Kasianov V. A. at the National Aviation University, Kyiv, Ukraine for about the last three decades.

In fact, the intelligence learning aspects might be and should be implemented to the modeling of the different nature system and processes, as for example, for the applicable features of the [13 – 17] publications.

Therefore, the goal of the presented herewith study is to demonstrate the advantages of the entropy paradigm [7 – 9, 12, 17 – 20] applicably to the generalized value of the air transportation management systems functioning learning potential.

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2. General approach

Intelligent air transportation management systems' functioning requires that the corresponding information flow be processed quite effectively and adequately. Participants of an economic process should have a possibility, taking into account available resources needed for running their own business, to choose that or another attainable (achievable, reachable) alternative in the problem-resource situation having been formed.

At this, proceeding from some theoretical speculations and [12, 17 – 20], the subject (the active element of the intelligent air transportation management system) distributes the preferences functions in accordance with the postulated optimality [12].

The problem is formulated as to discover the magnitude (possibly some relative value) and direction of the intelligent conflict situation certainty or uncertainty.

For that purpose, it is proposed to apply the entropy by Shannon, which has been developed for the probabilities. It is transformed for the intelligent conflict preferences similar to the references of [12, 17 – 20]:

$$H_{\pi} = -\sum_{i=1}^{N} \pi_i \ln \pi_i \ , \tag{1}$$

where i – the subscript that refers to the corresponding conflicting alternative that can be attained; N – the total number of the taken into consideration alternatives deemed to be conflicting; π_i – intelligent preferences functions that are to be found.

For the intelligent conflict management preferences π_i of conflicting alternatives it is going be used canonical expressions of [12, 17 – 20]:

$$\pi_i(t) = \frac{\exp[-\beta_i F_i]}{\sum_{j=1}^{N} \exp[-\beta_j F_j]} , \tag{2}$$

where β_i and β_j – the structure parameters, their corresponding values relate to the problem setting's objective functional of [12, 17 – 20], F_i and F_j – corresponding intelligent conflict management functions expressing the effectiveness of the i-th and j-th conflicting alternatives.

Modifications on the entropy of the view of (1), required for the stated problem solution, are going to be presented and described below herein.

3. Main Content

The traditional view entropy of (1) has some improperness to a certain degree. Let us say in a two conflicting alternatives situation the distribution of the intelligent conflict preferences are as follows:

$$\pi_1 = 0.351 \text{ and } \pi_2 = 1 - \pi_1 = 0.649 . \tag{3}$$

This means that entropy will be the same for the opposite situation situation:

$$\pi_1 = 0.649 \text{ and } \pi_2 = 1 - \pi_1 = 0.351 . \tag{4}$$

Thus, the entropy of the view (1) shows no difference with respect to the directions of the certainty or uncertainty of the intelligent conflict management alternating preferences. And that circumstance, as in the case of (3) and (4) with the mirror reflection preferences distribution change, pertains to any distribution of conflicting preferences. Hence, it is impossible to realize which uncertainty or certainty is a "good" one and which is a "bad". This attitude can be as "right" versus "wrong".

3.1. General provisions

The relative function [17] as hybrid pseudo-entropy fits the problem solution requirements:

$$\overline{H}_{\max-\frac{\Delta\pi}{|\Delta\pi|}} = \frac{H_{\max} - H_{\pi}}{H_{\max}} \frac{\Delta\pi}{|\Delta\pi|} = \frac{H_{\max} + \sum_{i=1}^{N} \pi(\sigma_i) \ln \pi(\sigma_i)}{H_{\max}} \frac{\left[\sum_{j=1}^{M} \pi\left(\sigma_j^{+}\right) - \sum_{k=1}^{L} \pi\left(\sigma_k^{-}\right) \right]}{\left| \sum_{j=1}^{M} \pi\left(\sigma_j^{+}\right) - \sum_{k=1}^{L} \pi\left(\sigma_k^{-}\right) \right|}, \tag{5}$$

where $H_{\max}$ – the maximally possible value of the entropy, in problems formulated in references of [12, 17 – 20] it is

$$H_{\max} = \ln N, \tag{6}$$

$\Delta\pi$ – the factor of the intelligent conflict management alternatives preferences functions domination, proposed in [17]:

$$\Delta\pi = \sum_{j=1}^{M} \pi\left(\sigma_j^{+}\right) - \sum_{k=1}^{L} \pi\left(\sigma_k^{-}\right), \tag{7}$$

where σ_j^{+} – alternatives that are considered to be positive and σ_k^{-} – alternatives with the negative content; M – the quantity of the positive alternatives; L – the quantity of the negative subset of the alternatives, [17]:

$$M + L = N. \tag{8}$$

3.2. Specific cases models construction

Let us consider a basic two-alternative situation:

$$v_T(m) = \sqrt[4]{\frac{4}{3} \frac{bm^2 g^2}{C_{x_0} \rho^2 S^2}}, \qquad v_L(m) = \sqrt[4]{4 \frac{bm^2 g^2}{C_{x_0} \rho^2 S^2}}, \tag{9}$$

where $v_T(m)$ – the speed of an aircraft horizontal flight that is optimal for the maximal duration, it is obtained as a function of the changeable mass of the aircraft m; b – the aircraft special aerodynamic coefficient; g – the acceleration of the force of gravity; C_{x_0} – one more aerodynamic coefficient of the aircraft drag when the force of the aircraft wing lift equals “zero”; ρ – the air density at the flight conditions; S – the area that characterizes the aircraft aerodynamics properties; $v_L(m)$ – one more optimal speed, this time for the aircraft flying in a horizontal path and intended for the maximal distance, it is also expressed as a function in the terms of the aircraft mass m when it changes.

The aircraft optimal speeds of (9) are obtained as extremum solutions delivering maximum values to the objective functionals of the aircraft horizontal flights; and these functions are considered in the presented study as the intelligent cyber conflict management effectiveness functions of the aircraft horizontal flight effectiveness.

Another two-alternative situation model is with taking into account the intelligent conflict management effectiveness functions in the view of the solution of the ordinary differential equation systems of the first order:

$$\left.\begin{aligned} \frac{dy_0}{dt} &= \left(1 - \frac{y_0}{Y_0}\right)\left(k_{00} y_0 - k_{10} y_0 y_1\right) \\ \frac{dy_1}{dt} &= \left(1 - \frac{y_1}{Y_1}\right)\left(-k_{11} y_1 + k_{01} y_0 y_1\right) \end{aligned}\right\}, \tag{10}$$

where y_0 – the first of the two alternative intelligent conflict management effectiveness functions; t – time; Y_0 – marginal value for the first of the two alternative intelligent conflict management effectiveness functions y_0; k_{00} – coefficient of the first function value supposed exponential growth; k_{10} – coefficient of the impact of the second of the two alternative intelligent cyber conflict management effectiveness functions upon the first one, which, by assumption, decreases the rate of the first conflicting function growth; y_1 – the second of the two alternative intelligent conflict management effectiveness functions; Y_1 – marginal value for the second of the two alternative intelligent conflict management effectiveness functions y_1; k_{11} – coefficient of the second function value supposed exponential decrease; k_{01} – coefficient of the impact of the first of the two alternative intelligent conflict management effectiveness functions upon the second one, which, by assumption, increases the rate of the second conflicting function growth.

The three-alternative case is like the previous but extended:

$$\left.\begin{aligned} \frac{dy_0}{dt} &= -k_{00}y_0\left(1-\frac{y_0}{Y_0}\right)+k_{10}y_1+k_{20}y_2 \\ \frac{dy_1}{dt} &= k_{01}y_0+k_{11}y_1\left(1-\frac{y_1}{Y_1}\right)-k_{01}k_{21}y_0y_2 \\ \frac{dy_2}{dt} &= k_{02}k_{12}y_0y_1-k_{22}y_2\left(1-\frac{y_2}{Y_2}\right) \end{aligned}\right\}, \tag{11}$$

where designations and interpretations of functions, coefficients, and values are analogous to the previous case (10), but it was customized and extended to the intelligent cyber conflict management situation with some three alternatives.

One more special case to be studied is when there are generalized parameters of the intelligent system learning.

The objective functional is

$$\Phi_\pi = -\sum_{i=1}^{2}\Pr_i \ln(\Pr_i)+\beta[\Pr_1 R+\Pr_2 R_0]+\gamma\left(\sum_{i=1}^{2}\Pr_i-1\right), \tag{12}$$

where $\Pr_1$ and $\Pr_2$ are the generalized perception functions of the two alternatives for resources; R and R_0 are the input learning variable and threshold value resources correspondingly; γ is the coefficient for the subjective preferences normalized assessment; it is likewise β, β_i, and β_j; they are the corresponding weight coefficients or they might be the structure parameters that are internal, also, these coefficients can be considered as the uncertainty Lagrange multipliers [12]. For the presented study these parameters are interpreted as the internal intelligent control parameters which have some properties of the intelligent object "attitude" to the alternatives [12].

The generalized perceptions functions of $\Pr_1$ and $\Pr_2$ are analogous to the preferences functions of (1) – (4).

Extremizing the objective functional (12) under conditions of

$$\frac{\partial \Phi_\pi}{\partial \pi_i}=0, \tag{13}$$

one can get the expressions similar to (2):

$$\Pr_1=\frac{\exp[\beta R]}{\exp[\beta R]+\exp[\beta R_0]}, \qquad \Pr_2=\frac{\exp[\beta R_0]}{\exp[\beta R]+\exp[\beta R_0]}. \tag{14}$$

The corresponding potential for the intelligence growth could be expressed as

$$V(R)=V_0 \Pr_2(R), \tag{15}$$

where V_0 is the amount of the intelligence potential available for the intelligence growth.

The intelligence growth output could be represented with one more generalized function:

$$Output(R)=V(R)R. \tag{16}$$

3.3. Solutions to the specific cases

In first situation (9) the solution is shown in the Figure 1.

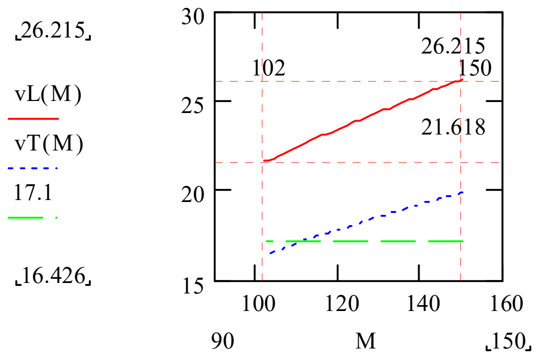

Figure 1: Intelligent conflict of optimal aircraft speeds

The designations in the Figure 1 are as follows: vL(M) is for $v_L(m)$, obtained by the second equation of (9); vT(M) is for $v_T(m)$, obtained by the first equation of (9) respectively.

The results of the system (10) solution are presented in the Figures 2 and 3.

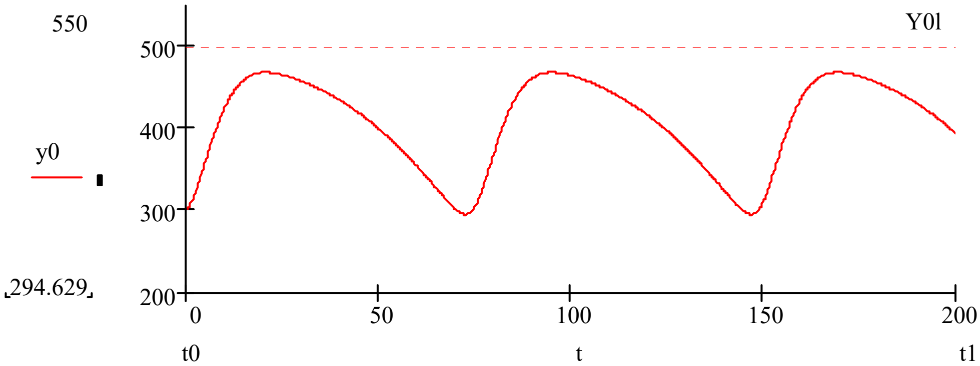

Figure 2: Intelligent cyber conflict system internal self-management for the self-growing effectiveness function

In the Figures 2 and 3 it is designated: y0 is for y_0, Y0l is for Y_0; and y1 is for y_1, Y1l is for Y_1 correspondingly.

The third case of solution, with the system of equations (11), is demonstrated with the diagrams plotted in the Figures 4 – 6.

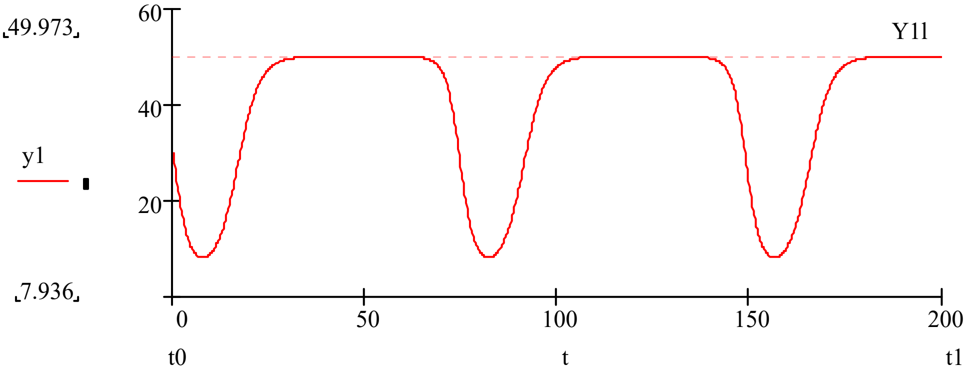

Figure 3: Intelligent conflict system internal self-management for the self-decreasing effectiveness function

The designations in the Figures 4 – 6 are analogous to those for the Figures 2 and 3, and simply extended to the considered three-alternative intelligent conflict situation.

The solutions expressed with the formulae of (14) – (16) to the special case of (12) under conditions of (13) has already been described above.

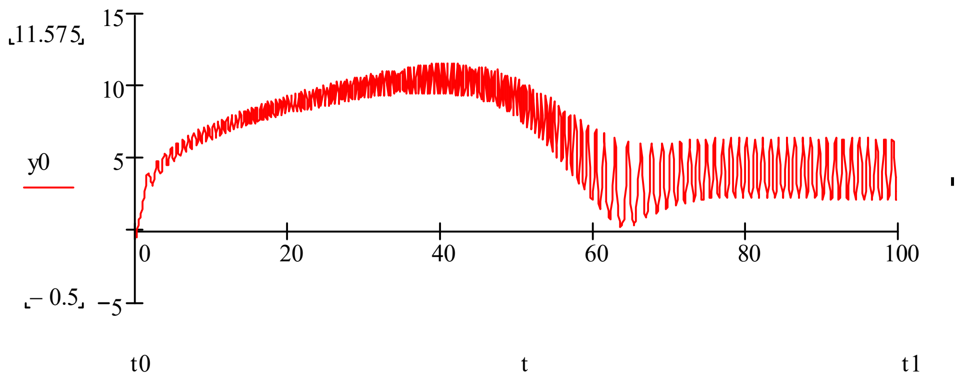

Figure 4: Intelligent conflict system internal self-management for the self-decreasing effectiveness function in case of the three-alternative situation

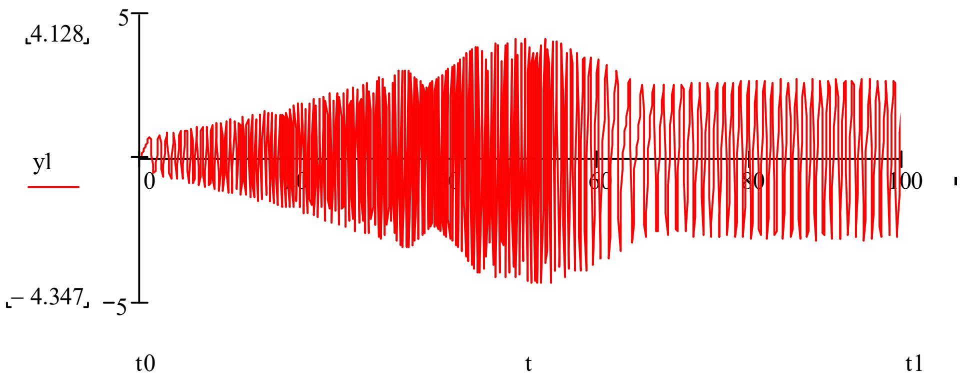

Figure 5: Intelligent conflict system internal self-management for the self-growing effectiveness function in case of the three-alternative situation

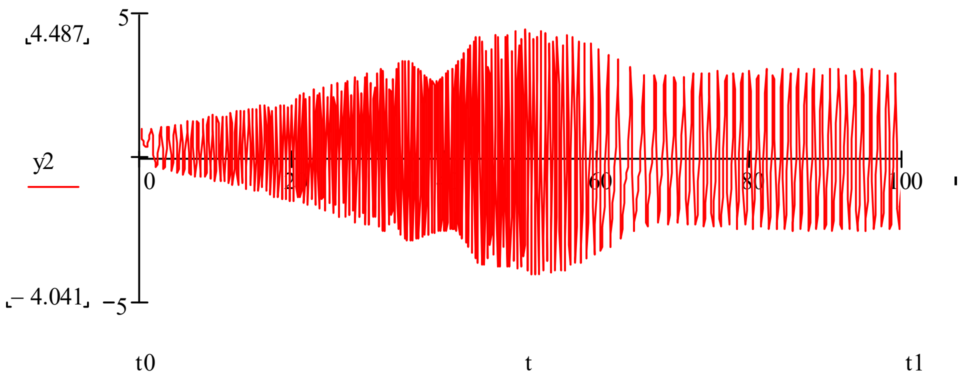

Figure 6: Intelligent conflict system internal self-management for the other self-decreasing effectiveness function in case of the three-alternative situation

3.4. Computer simulation

When the system of equation (11) is adapted to the composition that combines the complete self-management in the intelligent cyber conflict, it gives the results of computer simulation shown in the Figures 7 – 9.

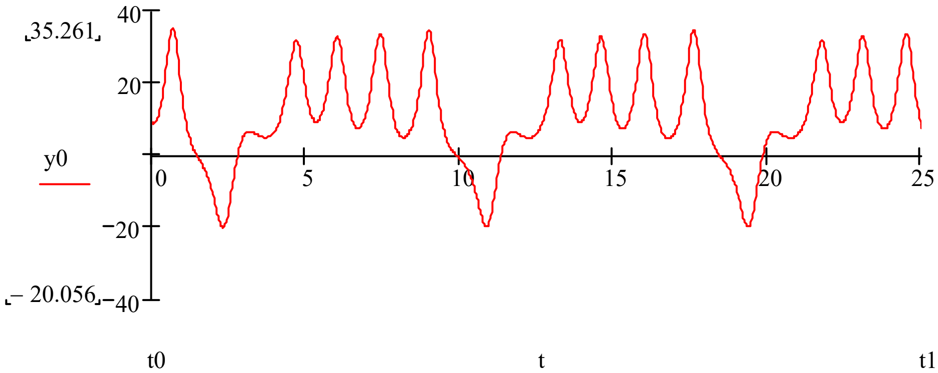

Figure 7: Intelligent conflict system complete internal self-management for the self-decreasing effectiveness function in case of the three-alternative situation

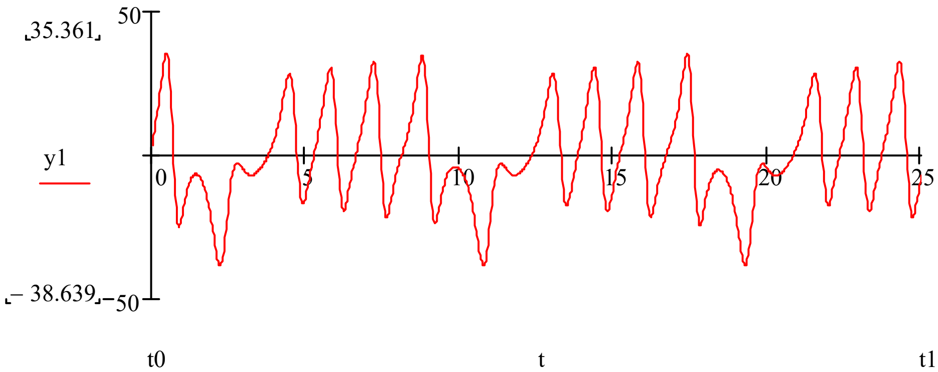

Figure 8: Intelligent conflict system complete internal self-management for the self-growing effectiveness function in case of the three-alternative situation

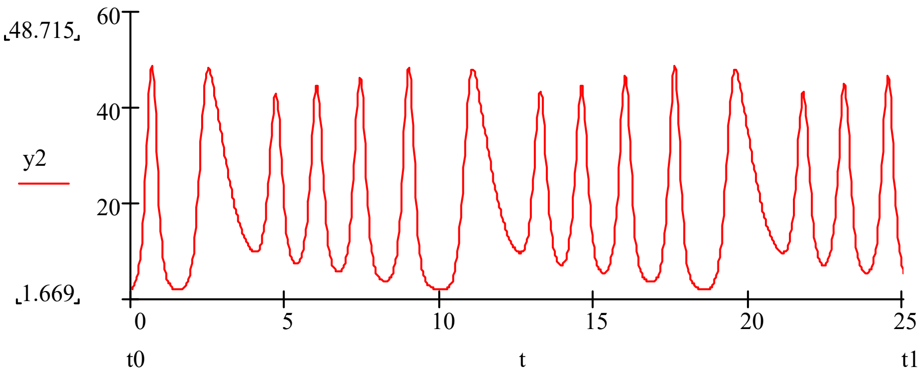

Figure 9: Intelligent conflict system complete internal self-management for the other self-decreasing effectiveness function in case of the three-alternative situation

The intelligent cyber conflict management preferences computed by (2) are illustrated in the Figure 10.

In the Figure 10: p0 stands for π_0, p1 stands for π_1, and p2 stands for π_2, correspondingly.

The traditional entropy of the intelligent conflict management preferences calculated by (1) is plotted in the Figure 11.

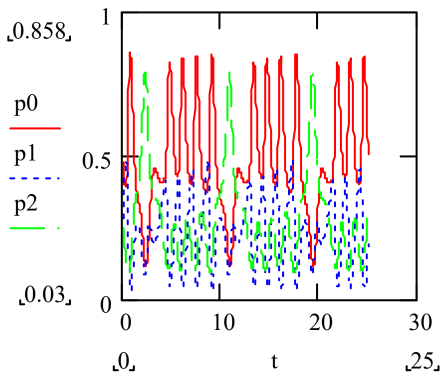

Figure 10: Intelligent conflict system complete internal self-management effectiveness functions preferences in case of the three-alternative situation

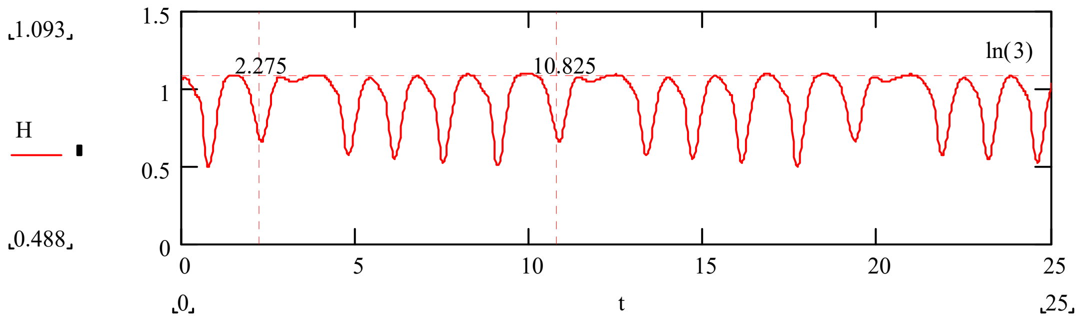

Figure 11: Entropy of intelligent conflict system complete internal self-management effectiveness functions preferences in case of the three-alternative situation

The pointed above hybrid pseudo-entropy relative function (5) of [17], when π_2 is a “positive” preference and π_0 and π_1 are not, that is they are considered as “negative” preferences, is shown in the Figure 12.

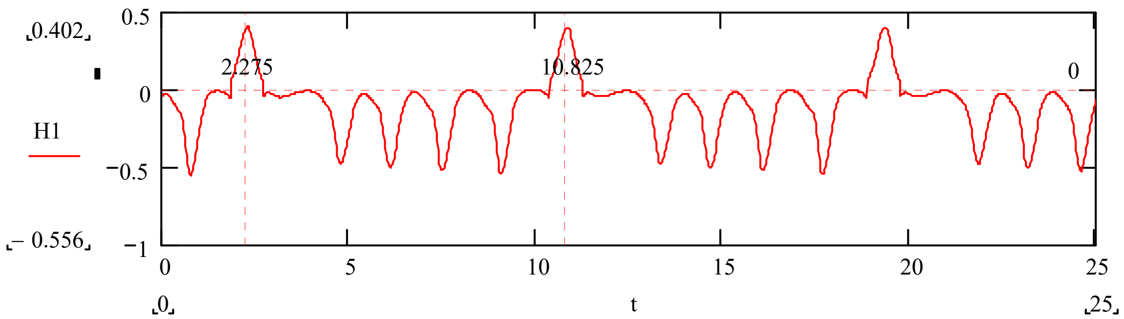

Figure 12: Hybrid pseudo-entropy relative function of intelligent conflict system complete internal self-management effectiveness functions preferences in case of the three-alternative situation

The results of computer simulation in case of (12) – (16) are represented in the Figures 13 – 15.

The generalized intelligence perception function curve, plotted in the Figure 13, is for the calculations by the second equation of (14) with the value of the threshold generalized resource of $R_0 = 100$.

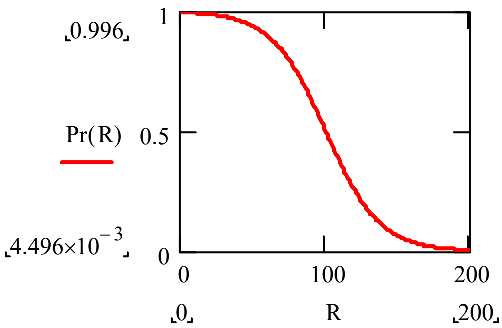

Figure 13: Generalized intelligence perception function

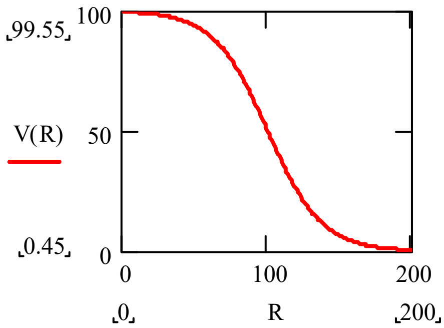

Figure 14: Generalized intelligence potential for the intelligence growth function

The generalized intelligence potential function (see the Figure 14) is used for the intelligence growth function shown in the Figure 15.

It is calculated with the amount of the intelligence potential available for the intelligence growth $V_0 = 100$.

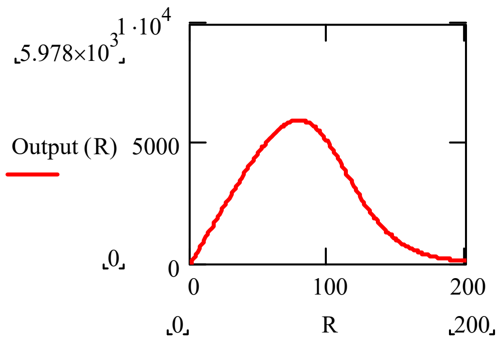

Figure 15: Generalized intelligence growth output function

4. Discussion

As can be seen from the results of the computer simulation (see the Figures 1 – 12) of the intelligent conflict management models involving entropy tools of (1) – (8) in application to (9) – (11), the hybrid pseudo-entropy relative function (5) of [17], of the intelligent conflict management effectiveness functions preferences has advantages over the traditional entropy (1).

The optimal generalized resource value for the intelligence growth output (see the Figures 13 – 15) is also obtainable with the help of the entropy paradigm (12) – (16).

The optimal value, which can be seen in the Figure 15, is lower than the threshold value accepted in the calculation simulations.

4.1. Comparison analysis to the known results

In the case of conflicting alternative speeds of the aircraft horizontal flight (see the curves calculated by the equations of (9) and plotted in the Figure 9), the intelligent cybernetic conflict management function with respect to the available and achievable conflicting alternatives (options) preferences functions entropy in the traditional view of (1) will not show the relative certainty or uncertainty degree for the alternatives, and its direction either. The proposed hybrid pseudo-entropy relative function (5) will show those required qualities and quantities.

Such effects are noticeable when comparing the entropies plotted in the Figures 11 and 12.

The entropy illustrated in the Figure 11 does not represent when, how much, and to which alternative or group of alternatives, that is to “good” or “bad”, “correct” or “wrong”, the intelligent conflict management has its inclination.

Whereas, the proposed combined hybrid pseudo-entropy relative function (5), that takes into account the relative value of the intelligent conflict management situation uncertainty, together with the composition with the intelligent conflict management effectiveness preferences functions index of domination, shows that there are periods of time when the certainty of the considered intelligent cyber conflict management has some definitely “positive” values. These values of time: $t \approx 2.275$ and $t \approx 10.825$ are represented in the Figure 12. Also, there is such effect at the time about $t \approx 19.325$.

The mentioned above points in time portrait practically not that much referred back to the traditional measure of uncertainty pictured in the Figure 11.

In the special case described with the equations of (12) – (16), illustrated in the Figures 13 – 15, the optimal input value of the generalized resources R delivers maximum value to the generalized intelligence growth output.

4.2. Evidently promising investigations

The calculation experimentations with the procedures described with the mathematical expressions of (1) – (11) and their adaptations have been conducted with several abstracted supposed data values and some initial conditions voluntary selected to a certain degree. Therefore, there is no need in their indication herewith.

Though the main ideas and provisions of the presented study are quite comprehensively performed in the models, there is a potential for the further research in the areas of the coefficient estimations. However, some other representations are also possible, as well as some other models of the similar interpretation could be elaborated.

The input value in the special case described with the equations of (12) – (16) is the generalized resources and it is necessary to investigate more complex models of the resource-output relations.

5. Conclusion

The entropy theory of conflicts in general sense can be successfully implemented to the solutions of the intelligent conflict management in the terms of the conflicts genesis, development, transitions, and exodus. The intelligent conflict being a primary reason for the intelligent cyber system motion can be properly managed with the relative function based upon the hybrid pseudo-entropy.

The optimal generalized input intelligent resources value found with the use of the resources generalized perceptions functions entropy conditional extremization ensures the maximum value to the generalized intelligence growth output. Further endeavors in the intelligent conflict management have prospects in the used values estimations and methodological modifications.

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