Simulation of Intelligent Air Transportation Management System Based upon Entropy Approach

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Abstract

The paper is devoted to the computer modeling for the optimal governing of the intelligent air transportation management system. The performed computer simulation is based upon the initial postulate of the subjective entropy maximum principle developed for the active systems control. The research and calculation experimentations are conducted for both losses ("harmfulness") and utilities ("usefulness") functions. It is discovered the important phenomenon unknown before, which is the shape of the phase diagrams for the preferences over the losses functions. Another novelty and significance of the findings related to the preference functions and entropy are that the conditional optimization of the subjective individuals' preferences functions entropy in conjunction with the proposed hybrid combined relative pseudo-entropy function helps determine the relative certainty/uncertainty degree concerning prevailing/dominating subjective preferences functions.

Keywords

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

1. Introduction

Computer modeling of intelligent systems is an actual and important task for scientific research and investigations. The urgency for such kinds of study is dictated by the contemporary informative world and intensifying development of intelligent technologies. Since air transportation management systems are functioning in some complex operational situations, there must be some corresponding scientific approaches allowing assessing the circumstances of the occurred multi-alternativeness.

One part of the influential factors, requiring computer modeling, is the issues of the aircraft as whole (including its powerplants) proper maintenance and repair [1, 2] in order to keep the reliability of the aeronautical engineering and the flight safety of the entire aircraft itself [3, 4].

Elements of the intelligence, either natural or artificial, are present at the air transportation management system's making governing decisions and operational alternatives choice. Such processes might be considered from the point of view of the utility theory [5, 6].

Anyway, the entropy paradigm formulated in [7 – 9], and used widely in science nowadays [10], with taking into account economic aspects [11], realized in the theory of active systems and subjective preferences [12], should be rather effectively implemented to the problems of the intelligent aviation radio equipment reliability parameters monitoring [13], revealing needed properties of new materials [14], neural networks of different kinds modeling [15, 16].

The essential feature is the application of such type of the entropy paradigm as used in [7 – 10, 12, 17 – 20] in order to model the properties of the intelligent air transportation management system's optimal behavior in conditions of the available operational multi-alternativeness causing the uncertainty of the individuals' subjective functions of their preferences.

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2. Development of theoretical models with the elements of simulation

The modeling of the intelligent air transportation management system's optimal behavior requires a closer look into theoretical provisions. The uncertainty of the individuals' subjective preferences functions should be assessed with the subjective entropy [12]. The well-known Jaynes' principle of the entropy maximum [7 – 9] implemented into the field of aviation will help cope with the problems connected with the notorious human factor. First, let us consider a portion of the developments dedicated to the subjective preferences theory provisions.

2.1. Basic concept

It is proposed to apply the generalized model, taking into account the operational uncertainty with the help of the objective functional of the intelligent air transportation management system, in the view of [12]:

$$\Phi_\pi^- = -\sum_{i=1}^{N} \pi^-(\sigma_i) \ln \pi^-(\sigma_i) - \beta \sum_{i=1}^{N} \pi^-(\sigma_i) L(\sigma_i) + \gamma \left[\sum_{i=1}^{N} \pi^-(\sigma_i) - 1 \right], \tag{1}$$

where $\pi^-(\sigma_i)$ – corresponding subjective individual's preference function of the responsible decision making person distributed with respect to the negative qualities of the achievable for the person's goals alternatives σ_i; β and γ – the values, introduced in the objective intelligent air transportation management system functional (1), in some respect, could be defined as endogenous parameters reflecting certain features and properties of psych, or internal parameters of the intelligent air transportation management system, the uncertain Lagrange multipliers, some coefficients or weight coefficients at the specific problem settings [12]; $L(\sigma_i)$ – the corresponding function of the personally estimated losses ("harmfulness") related with the available alternatives; the individual distinguishes a certain one-sided attitude to the managerial process.

The first member in the intelligent air transportation management system objective functional (1) having the expression of

$$-\sum_{i=1}^{N} \pi^-(\sigma_i) \ln \pi^-(\sigma_i), \tag{2}$$

is the subjective entropy H_π, that is the measure of the operational multi-alternativeness uncertainty of the individuals' preferences functions of the effectiveness (in the given case study: losses $L(\sigma_i)$ related to the alternatives).

The last member in the intelligent air transportation management system objective functional (1) having the expression of

$$\sum_{i=1}^{N} \pi^-(\sigma_i) - 1, \tag{3}$$

is the normalizing condition.

On the contrary, formulating the objective functional as, [12]:

$$\Phi_\pi^+ = -\sum_{i=1}^{N} \pi^+(\sigma_i) \ln \pi^+(\sigma_i) + \beta \sum_{i=1}^{N} \pi^+(\sigma_i) U(\sigma_i) + \gamma \left[\sum_{i=1}^{N} \pi^+(\sigma_i) - 1 \right], \tag{4}$$

where $\pi^+(\sigma_i)$ – corresponding positive subjective individual's preference function of the responsible decision making person; $U(\sigma_i)$ – the corresponding function of the personally estimated utility related with the available alternatives; the individual distinguishes a certain second-sided attitude to the managerial process.

Both formulation of (1) and (4) that is both the negative (losses, harmfulness) and positive (utility, usefulness) estimations are possible.

And the both-sided estimated managerial process of (1) and (4) is extremized with the use of the necessary conditions for the subjective preferences functions entropy conditional optimization in the view of

$$\frac{\partial \Phi_{\pi}^{-}}{\partial \pi^{-}(\sigma_i)} = 0, \qquad \frac{\partial \Phi_{\pi}^{+}}{\partial \pi^{+}(\sigma_i)} = 0, \qquad \left(\forall i \in \overline{1, N}\right). \tag{5}$$

For both senses of (1) and (4) the conditions of (5) yield the so-called canonical distributions of the subjective preferences functions [12].

In cases of the object (item, thing) subjective preferences these canonical distributions of the preferences functions are conventionally called: the subjective preferences functions distributions of the first kind [12].

The optimal distributions are as follows, [12]:

$$\pi^{-}(\sigma_i) = \frac{e^{-\beta_L L(\sigma_i)}}{\sum_{j=1}^{N} e^{-\beta_L L(\sigma_i)}}, \qquad \pi^{+}(\sigma_i) = \frac{e^{\beta_U U(\sigma_i)}}{\sum_{j=1}^{N} e^{\beta_U U(\sigma_i)}}, \tag{6}$$

where β_L and γ_L – corresponding coefficients with the subscript for the objective intelligent air transportation management system functional of (1) having related with the negative sense alternatives σ_i effectiveness estimations; and β_U and γ_U – corresponding coefficients if the subjective attention is drawn to the positive features, in generally speaking terms to the same set of the alternatives.

Illustration of the theoretical speculations, described with the expressions of (1) – (6), is in [12] too; and it is shown in the Figure 1.

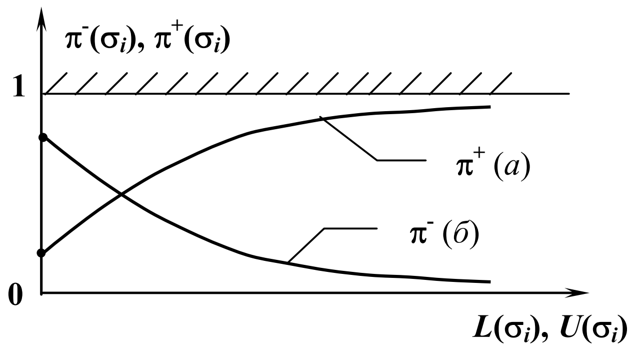

Figure 1: The shape of the preferences functions, [12]

Now, there arises a big conceptual question. The curve denoted as $\pi^{-}(\sigma_i)$ is monotonously decreasing as the corresponding harmfulness function increases, but the point is that, that this is not always so, because, if it, the preference function for some of the alternatives, decreases, it means that for the other alternatives it symmetrically increases (absolutely like $\pi^{+}(\sigma_i)$ preference shown in the Figure 1 as well).

Let us demonstrate this ideological collision with the simplest modeling.

2.2. Modeling

For the simplest modeling let us consider the linear increase of harmfulness (losses) functions with respect to a distinguishing parameter for a three-alternative case.

The computational data are as follow:

$$\sigma = -100 \ldots 100, \qquad \beta_L = 0.009, \qquad L_1(\sigma) = 10\sigma, \qquad L_2(\sigma) = 15\sigma, \qquad L_3(\sigma) = 20\sigma. \tag{7}$$

The results of the simulation are shown in the Figures 2 – 5.

The diagrams plotted in the Figure 2 are for the losses (“harmfulness”) functions values computed by the last three equations of (7) correspondingly.

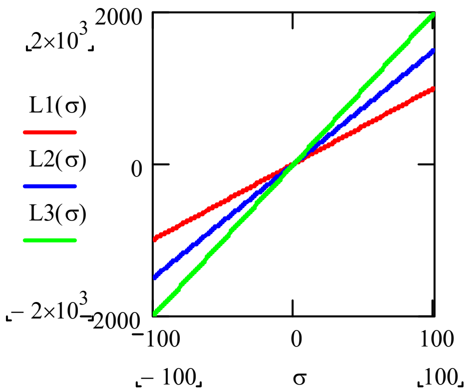

Figure 2: Harmfulness functions

The next up is the illustration for the subjective individuals' preferences functions represented in the Figure 3.

Also, the normalizing condition (3) check is realized with the "one" value made visible in the Figure 3.

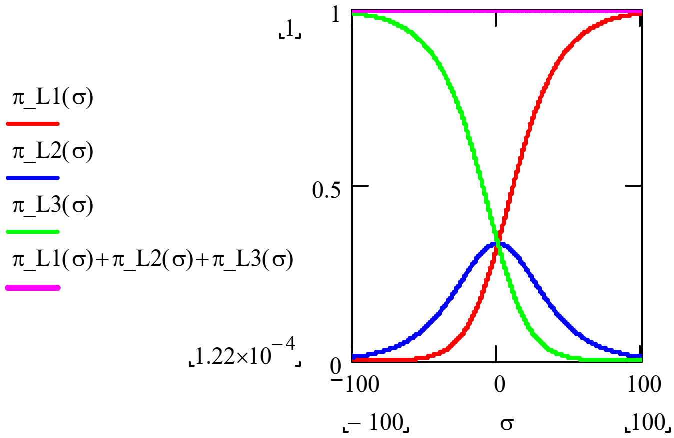

Figure 3: Subjective preferences functions

In order to get the phase portrait equivalent to the one shown in the Figure 1, the diagrams in the Figure 4 are plotted. The normalizing conditions (3) check is presented there as well.

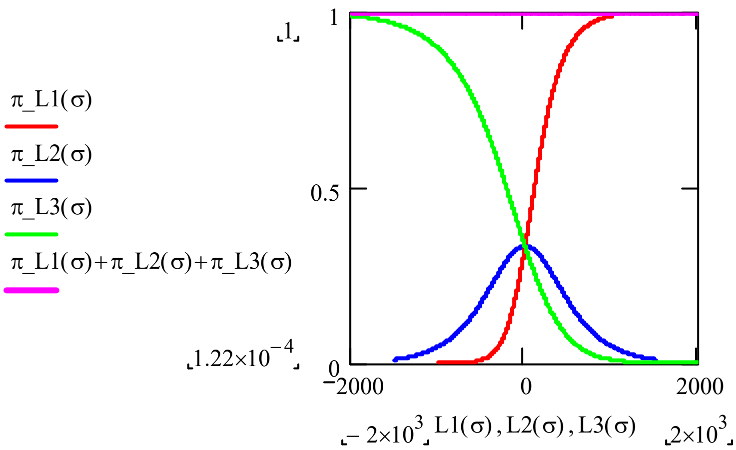

Figure 4: Subjective preferences functions with respect to losses functions

Thus, the diagram of $\pi^{-}(\sigma_i)$ shown in the Figure 1 deals with just a very particular case.

The subjective entropy of H_π, computed with the help of the expression (2), of the subjective individuals' preferences functions $\pi^{-}(\sigma_i)$, computed with the use of the first equation of the expressions of (6), is illustrated in the Figure 5.

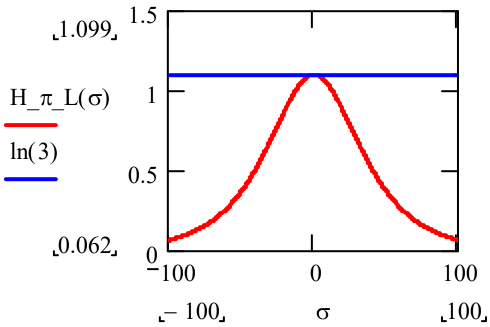

Figure 5: Subjective preferences functions with respect to losses functions

The maximal subjective entropy value, which is

$$\ln(3), \tag{8}$$

is also shown in the Figure 5.

Here, one more important theoretical question arises, whether the traditional view entropy H_π, having the expression of (2), is able to distinguish what the preferences distributional uncertainty the entropy H_π determines.

In order to clarify this issue, the relative combined pseudo-entropy function is proposed to be used in addition to the entropy H_π of (2).

2.3. Modeling based upon pseudo-entropy function

As it is seen from the Figure 5, the traditional view subjective entropy of H_π, computed with the help of the expression (2), is incapable to clarify the entropy value for the specific distribution of the subjective individuals' preferences functions $\pi^{-}(\sigma_i)$.

Therefore, it is proposed to make use of the measure of the certainty/uncertainty in the view of the hybrid model of the combined pseudo-entropy function of the subjective functions [17]:

$$\overline{H}_{\max-\frac{\Delta\pi}{|\Delta\pi|}} = \frac{H_{\max} - H_\pi}{H_{\max}}\frac{\Delta\pi}{|\Delta\pi|} = \frac{H_{\max} + \sum_{i=1}^{N}\pi(\sigma_i)\ln\pi(\sigma_i)}{H_{\max}} \frac{\left[\sum_{j=1}^{M}\pi(\sigma_j^{+}) - \sum_{k=1}^{L}\pi(\sigma_k^{-})\right]}{\left|\sum_{j=1}^{M}\pi(\sigma_j^{+}) - \sum_{k=1}^{L}\pi(\sigma_k^{-})\right|}, \tag{9}$$

where $H_{\max}$ – maximal subjective entropy value, in discrete alternatives problem settings this value constitutes:

$$H_{\max} = \ln N; \tag{10}$$

$\Delta\pi$ – factor/index of the preferences functions prevailing/dominance:

$$\Delta\pi = \sum_{j=1}^{M}\pi(\sigma_j^{+}) - \sum_{k=1}^{L}\pi(\sigma_k^{-}), \tag{11}$$

where σ_j^{+} – positive and σ_k^{-} – negative alternatives correspondingly; M – the number of the positive alternatives; L – the number of the negative alternatives in respect:

$$M + L = N. \tag{12}$$

Thus, computer modeling allows, designating some subjective individuals' preferences functions as "positive" or "negative", making it visible which alternative preference dominates in the certainty/uncertainty degree. Moreover, it is important that the value of (9) is relative which is also more convenient.

2.4. Simulation

For the case considered above, it is possible to distinguish alternatives subjective preferences functions one by one. For the first alternative the preferences prevailing factor (11) gives:

$$\Delta\pi = \pi_1 - (\pi_2 + \pi_3). \tag{13}$$

Computation results for (6) – (12), with (13) for (11), are shown in the Figure 6.

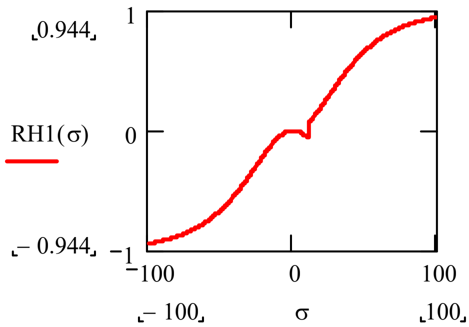

Figure 6: Relative pseudo-entropy function for the first alternative function dominance

The curve in the diagram in the Figure 6 is plotted by the calculations with formula (9) where (13) stands for (11). Similar procedures for the other two alternatives:

$$\Delta\pi = \pi_2 - (\pi_1 + \pi_3) \quad \text{and} \quad \Delta\pi = \pi_3 - (\pi_1 + \pi_2). \tag{14}$$

bring the results shown in the Figures 7 and 8.

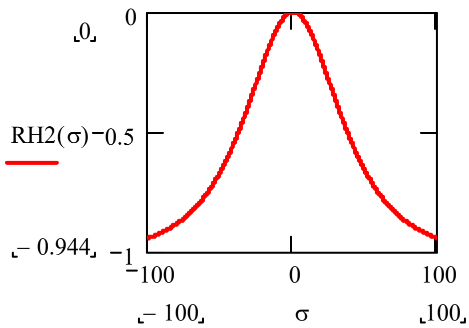

Figure 7: Relative pseudo-entropy function for the second alternative function dominance

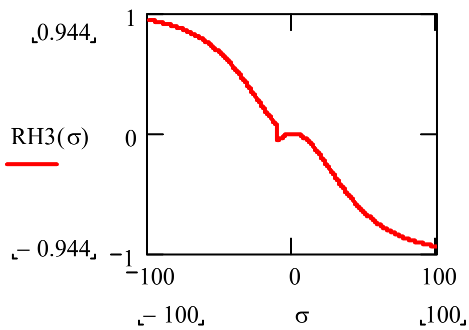

Figure 8: Relative pseudo-entropy function for the third alternative function dominance

All the three pseudo-entropy functions are shown in the Figure 9.

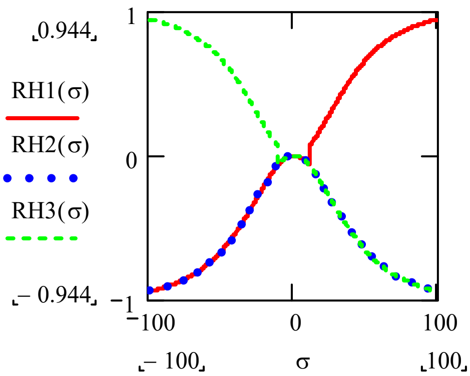

Figure 9: Relative pseudo-entropy functions for the three alternative functions dominance

For the visibility and comparison analysis the entropies and preferences functions are represented in the Figure 10.

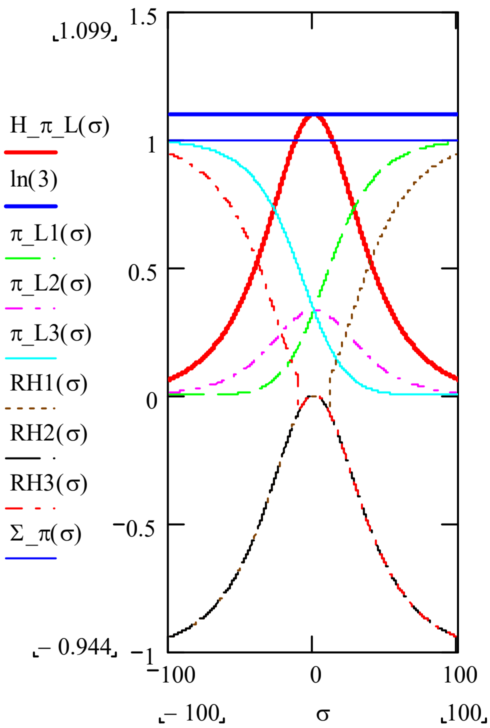

Figure 10: Relative pseudo-entropy functions for the three alternative functions dominance

2.5. Modeling a more general case

Now, it is possible to consider some more generalized models when some of the functions of losses are nonlinear.

The data that are different from the above case are as follows:

$$L_2(\sigma) = -0.00225\sigma^3, \qquad L_3(\sigma) = -0.2\sigma^2. \tag{15}$$

The results of the computer modeling calculation simulations in the style of (1) – (14) with the corresponding functions of (15) are represented in the Figures 11 – 19.

The diagrams for functions of losses (harmfulness) are shown in the Figure 11.

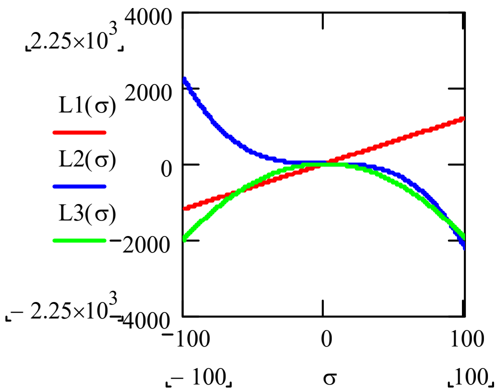

Figure 11: Functions of losses for the three alternatives

The subjective preferences functions are portrayed in the Figure 12.

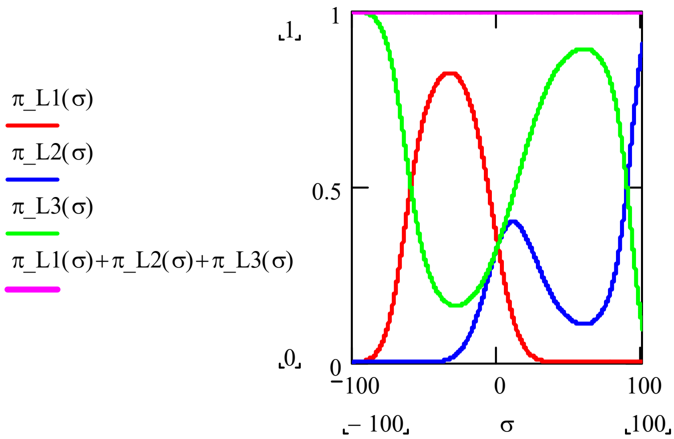

Figure 12: Functions of subjective preferences for the three alternatives

The normalizing conditions are also presented in the Figure 12.

Phase diagrams of the subjective individuals' preferences functions with regards to the corresponding harmfulness functions are illustrated in the Figure 13.

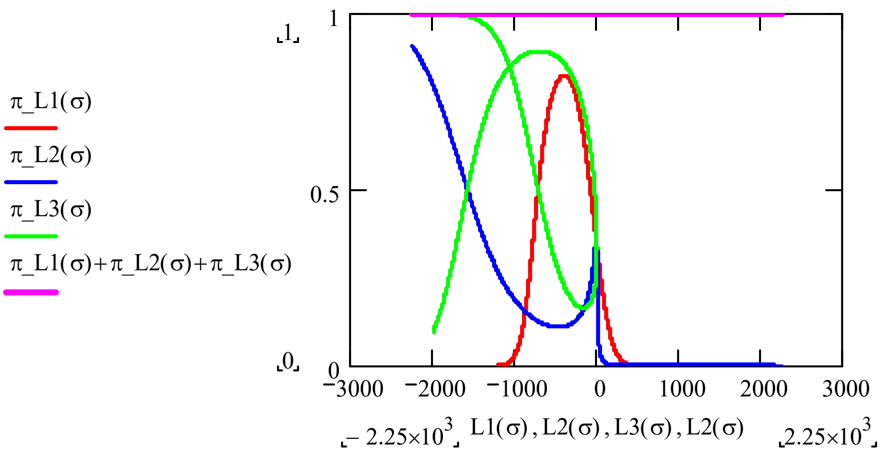

Figure 13: Phase diagrams of subjective preferences functions with respect to the losses functions for the three alternatives

The phase portrays as well as the check line for the normalizing conditions are, in fact, the corresponding projections of the curves within the three coordinates reference system (see and compare the Figures 11 – 13). The traditional view subjective entropy of the individuals' preferences functions is shown in the Figure 14.

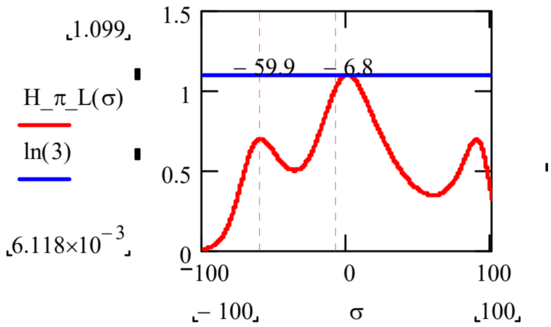

Figure 14: Traditional view subjective entropy of the individuals' preferences functions

The relative pseudo-entropy function in the case of the first alternative preference function domination is shown in the Figure 15.

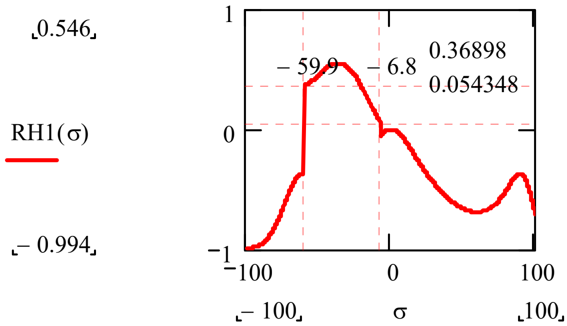

Figure 15: Relative pseudo-entropy function for the first alternative subjective individuals' preferences function prevailing

As for the second alternative preference function prevailing, the relative pseudo-entropy function is shown in the Figure 16.

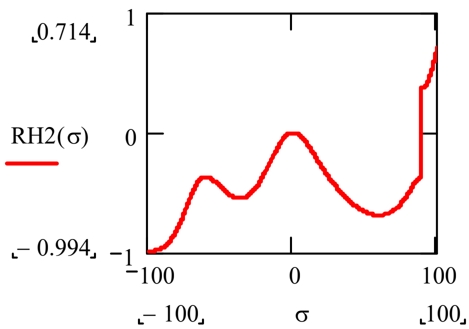

Figure 16: Relative pseudo-entropy function for the second alternative subjective individuals' preferences function dominance

The third alternative preference function domination impact upon the relative pseudo-entropy function is represented in the Figure 17.

The relative pseudo-entropy functions for all three cases of the three alternative preference functions domination are shown in the Figure 18.

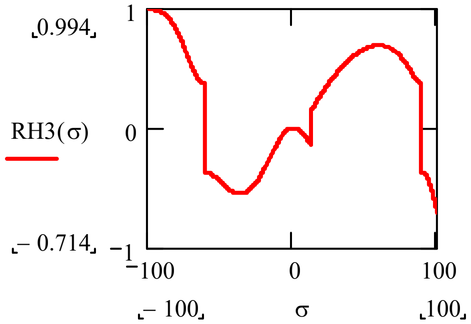

Figure 17: Relative pseudo-entropy function for the third alternative subjective individuals' preferences function prevalence

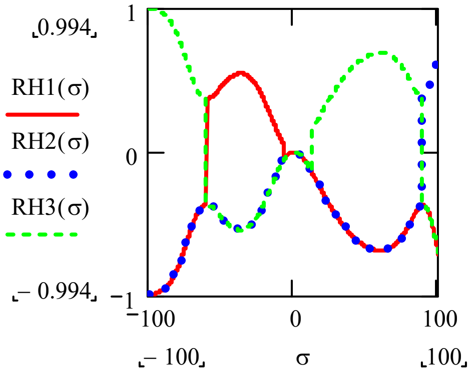

Figure 18: Relative pseudo-entropy functions for the three alternatives subjective individuals' preferences functions prevalence

The diagrams showing all curves of the case study are plotted the Figure 19.

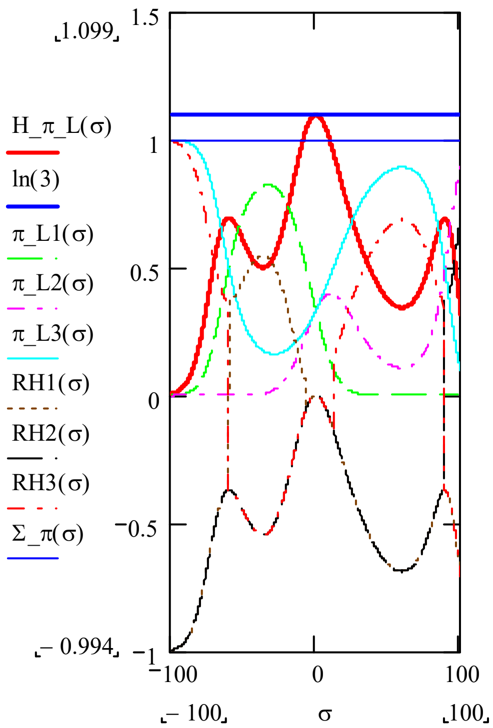

Figure 19: All curves of the case study

3. Discussion

Computer modeling of intelligent systems should be based upon the laws and regularities of the natural intellect functioning. One of such regularities is the available for an individual's alternatives choice subjective preferences optimal distribution in accordance with the postulated in subjective analysis theory of preferences principle which is called the subjective entropy maximum principle.

Active air transportation systems management elements have to include the corresponding subjective individual's preferences functions of the responsible decision making persons distributed with respect to the negative qualities of the achievable for the person's goals alternatives modeled with the objective intelligent air transportation management system functional (1). Subjective entropy (2) and normalizing constraint (3) are essential components of the objective functionals (1) and (4) for obtaining solutions (6) on conditions of (5).

However, the generally accepted character of the subjective preferences functions (6) dependence upon the functions of losses ("harmfulness") (illustrated in the Figure 1, [12]), is now broadened to the understandings of the modeled cases (7) – (15) (see the Figures 2 – 19). The point is that the subjective individuals' preferences functions (6) presumably measure the relative either harmfulness (losses) or the utilities ("usefulness") of the attainable alternatives due to the subjective preferences entropy conditional optimization principle.

That is why the shape of the phase diagrams for preferences to losses functions (illustrated in the Figure 1, [12]) is revealed to be correct only for the greatest of the linear case losses functions with respect to the determining parameter (see and compare the Figures 1 – 4 and Figures 11 – 13 correspondingly).

The proposed relative pseudo-entropy function (9) happened to be helpful in determining the relative certainty/uncertainty degree concerning prevailing/dominating preference (11). For instance, the hybrid relative combined pseudo-entropy function (9) (see the Figure 15) in the diapason of the determining parameter of $[-59.9 \ldots -6.8]$ shows the systems certainty increase with the following decrease because of the first alternative subjective preference function domination. Although the traditional view entropy (2) is incapable to distinguish such phenomenon (see and compare the Figures 15 and 14 in regards). For other diapasons the certainty/uncertainty varies in negative values, which means that the first alternative subjective preference function has no prevalence (13) (also see and compare the Figures 15 and 14 in correspondences). The same effectiveness of the proposed hybrid relative combined pseudo-entropy function (9) comparatively to the traditional view entropy (2) is visible in the Figures 14 and 16 – 19; as well as in the Figures 5 – 10. The relative value of the pseudo-entropy function (9), having "positive certainty": "+1", "negative certainty": "-1", and "uncertainty": "0" values, is more convenient rather than the bare value of the traditional view entropy (2). The same is observed for the utilities ("usefulness") subjective preferences functions entropy conditional optimization described with the formulas of (4) and (6).

4. Conclusion

Computer modeling of the intelligent air transportation management system functioning in the conditions of the operational alternatives subjective preferences uncertainty helps reveal the important phenomenon unknown before. That is the shape of the phase diagrams for the preferences to losses functions. 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.

Further studies should investigate more special cases of the intelligent systems multi-alternativeness.

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