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Content

CONTROL PROCESSES

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Запропоновано модель безперервного управління процедурою взаємного фінансового інвестування для системи підтримки прийняття рішень. Модель дозволяє оптимізувати знаходження різноваріантних стратегій у випадках взаємного фінансовому інвестування об'єктів. Модель реалізована на мові високого рівня С++ в програмному продукті «Система підтримки рішень по взаємному інвестуванню – SSDMI». Система пройшла апробацію в ряді інвестиційних проектів

Ключові слова: система підтримки рішень, інвестування, фінансовий капітал, вибір стратегії, теорія ігор

Описана модель непрерывного управления процедурой взаимного финансового инвестирования для системы поддержки принятия решений. Модель позволяет оптимизировать нахождение разновариантных стратегий во взаимном финансовом инвестировании объектов. Модель реализована на языке высокого уровня С++ в программном продукте «Система поддержки решений по взаимному инвестированию – SSDMI», которая прошла апробацию в ряде инвестиционных проектов

Ключевые слова: система поддержки решений, инвестирование, финансовый капитал, выбор стратегии, теория игр

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DEVELOPMENT OF THE DECISION MAKING SUPPORT SYSTEM TO CONTROL A PROCEDURE OF FINANCIAL INVESTMENT

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1. Introduction

Investing in innovative projects, for example, in the field of information technologies and cybersecurity is in many cases characterized by a high degree of uncertainty and risk. To improve efficiency and optimize procedures of project assessment and decision making, associated with investing, "inteligent" data analysis systems are now involved increasingly often [1]. In addition, various decision support systems (DSS) have gained good reputation for solving similar problems [2].

Filling of DSS and their separate modules, directly responsible for analysis and solution of problems, is performed by introduction of the units that contain programmed algorithms into economic-mathematical models. However, few DSS enable optimization of procedures, associated with finding multi-variant strategies in mutual financial investment of projects [3, 4]. In this context, it is a relevant task to develop new economic-mathematical models for DSS, which allow adequate description of actual economic processes, caused by increasing competitiveness of various companies, corporations and states.

2. Literature review and problem statement

The problem of effective financial investment and control over this process is one of the most important in the financial sector [1]. However, studies very often are of purely economic nature [2] and do not take into account trends, associated with implementation of information technologies in the processes of control and decision-making [3]. Economic aspects of the processes of mutual investment are described in papers [4–6]. A shortcoming of these studies is the lack of relevant recommendations on formulation of strategies for mutual financial investment.

A separate direction of research in this area was represented by papers, dedicated to application of various expert systems [7–9] and decision support systems (DSS) [10, 11] for selection of rational investment strategies [12]. The approaches, developed by the authors [8, 9, 11], do not make it possible to find effective recommendations and investment management strategy while solving this problem [12, 13]. In articles [14, 15], the models of assessment of mutual investment processes were proposed. The authors do not take into account the effect of changes of some factors influencing effectiveness of investment projects, in particular, the issue of strengthening or weakening of the investor's currency was not considered. Papers [16, 17] proposed the models of selection of strategies of investment processes, which are based on the theory of differential games. However, the authors did not develop the tools for solution of differential games for mutual investment problems. Article [18] considered the possibility of using the game theory in DSS for estimation of attractiveness of investment projects. Software implementation was not described by the authors, no specific recommendations for formulation of strategies for mutual financial investment were made either.

This fact necessitates development of new DSS models, which would give the opportunity to find optimal strategies of mutual financial investment. This may be achieved, in particular, through application of the methods of the theory of differential quality games with some terminal surfaces.

Thus, as analysis of research in this area showed, the problem of further development of models and relevant algorithms for decision support systems in problems of continuous mutual investment remains relevant. The latter is especially important for cases where it is necessary to take into account many parameters that describe the process of mutual investment.

3. The aim and objectives of the study

The aim of present research is to develop a model for DSS of continuous mutual investment, taking into account many parameters, which adequately describes the investment process. The special feature of the model is that such an investment process is described by bilinear differential equations with arbitrary coefficients with bilinear functions.

To accomplish the set goal, the following tasks had to be solved:

– to develop a model for finding investment control strategies for different ratios of parameters of the investment process;

– to implement the model in a high-level programming language in DSS module and conduct computational experiment.

4. The model of mutual financial investment for a decision support system

An investor from the country, where the United States dollar is the currency, having free capital, is trying to select the most preferable options for its investment. To do this, he chooses the counterparty, i.e. an object for investing his funds in a country, where the currency is euro. This object can be, for example, the economy of another country, or a corporation or, for example, information and communication systems, and so on. There is interaction of the investor and its counterparty. Entering this interaction, the investor and the counterparty seek to achieve their goals. The investor seeks to increase his capital, while the counterparty aims to improve his financial and economic indicators, one of which can be his capital. Subsequently, without decreasing generality, we will assume that the counterparty also seeks to increase its capital. However, the interests that do not coincide, non-optimal control and existence of uncertainty do not always make it possible to achieve interaction of both sides at the same time. If the investor faces such problem regularly, it is advisable to use DSS.

We will formalize the investment process in the assumption that the investor is the investment company, the counterparty is the financial corporation in another country.

We will give description of the "basic" process – the process of interaction between the investment company of one country and the corporation of another country. The investment company, having some free resources (its investment capital) increases them by α_1 times (where α_1 is rate of increase of the company's resources) and then decides which of these resources will be invested in active operations. These operations include allocation of resources for investment projects of the corporation and payment of the debts the company has by that point of time. We will assume that the same things are done by the corporation with respect to this investment company. We will note that if the corporation does not invest its resources in the investment company, then, as it will follow from the stated below, that will be a particular case of the variant with investment of the corporation's capital in the investment company. Described above interactions between the company and the corporation will act under the following assumptions:

a) the investment company controls financial resources x, estimated in dollars (USD);

b) the corporation controls financial resources y, estimated in euros (EUR);

c) during interaction, the ratio of the dollar to the euro (dollar's exchange rate) k_d remains constant.

If these assumptions are met, the interaction happens as follows.

First, the investor determines the share of resources, allocated for mutual active transactions with the counterparty. After the investment company and the counterparty have leveraged the resources allocated for mutual transactions, the following system of differential equations is solved:

$$dx(t)/dt=-x(t)+\alpha_1(t)\cdot x(t)+ +[(1-\beta_1(t))\cdot(a_1(t)+r_1(t))-1]\cdot u(t)\cdot\alpha_1(t)\cdot x(t)+ +[1-((a_2(t)+r_2(t))\cdot(1-\beta_2(t))]\cdot v(t)\cdot\alpha_2(t)\cdot y(t)/k_d; \quad (1)$$

$$dy(t)/dt=-y(t)+\alpha_2(t)\cdot y(t)+ +[(1-\beta_2(t))\cdot(a_2(t)+r_2(t))-1]\cdot v(t)\cdot\alpha_2(t)\cdot y(t)+ +[1-((a_1(t)+r_1(t))\cdot(1-\beta_1(t))]\cdot u(t)\cdot\alpha_1(t)\cdot x(t)\cdot k_d. \quad (2)$$

Thus, at the point of time t magnitude $dx(t)/dt$ of the company (in dollars) will be equal to the sum of the following summands:

– magnitude $\alpha_1(t)\cdot x(t)$, magnitude of per cent $a_1(t)\times$ $\times(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)$ for invested financial resources $(1-$ $-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)$ of the company;

– magnitude $r_1(t)\cdot(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\cdot x(t)$, characterizing the share of "returned" investment resource $(1-\beta_1(t))\times$ $\times u(t)\cdot\alpha_1(t)\cdot x(t)$ of the company;

– magnitudes of "non-returned" assets (investment) $[\{(1-r_2(t))\cdot(1-\beta_2(t))/k_d\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)$ of the corporation (in dollars);

– magnitude $\{\beta_2(t)/k_d\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)$, characterizing payment of the corporation's debt to the company.

From this sum we deduct:

– magnitude of financial resource $x(t)$;

– magnitude $u(t)\cdot\beta_1(t)\cdot\alpha_1(t)\cdot x(t)$, allocated to pay the debt of the company to the corporation by moment of time t;

– magnitude $u(t)\cdot(1-\beta_1(t))\cdot\alpha_1(t)\cdot x(t)$, allocated for transactions of the company (investment) at the moment of time t;

– magnitude $\{a_2(t)\cdot(1-\beta_2(t))/k_d\}\cdot v(t)\cdot\alpha_2(t)\cdot y(t)$ is the amount of per cent for investment resources $\{(1-\beta_2(t))/k_d\}\times \times v(t)\cdot\alpha_2(t)\cdot y(t)$ of the corporation.

Magnitude d$y(t)/dt$ (in Euro) at the moment of time t will be equal to the sum of all the following summands:

– magnitude $\alpha_2(t)\cdot y(t)$, amount of per cent $a_2(t)\cdot(1-\beta_2(t))\times \times v(t)\cdot\alpha_2(t)\cdot y(t)$ for invested financial resources $(1-\beta_2(t))\times \times v(t)\cdot\alpha_2(t)\cdot y(t)$ of the corporation;

– magnitude $r_2(t)\cdot(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)$, characterizes the share of "returned" investment resource $(1-\beta_2(t))\times \times v(t)\cdot\alpha_2(t)\cdot y$(t) by the company to the corporation;

– magnitude of "non-returned" assets (investment) $(1-r_1(t))\cdot(1-\beta_1(t))\cdot u(t)k_d\cdot\alpha_1(t)\cdot x(t)$ to the company by the corporation, magnitude $u(t)\cdot\beta_1(t)\cdot k_d\cdot\alpha_1(t)\cdot x(t)$, characterizing payment of debts to the corporation by the company.

From this sum we deduct:

– magnitude of financial resource $y(t)$, magnitude $v(t)\cdot\beta_2(t)\cdot\alpha_2(t)\cdot y(t)$, allocated by the corporation to pay debts it has to the company by the moment of time t;

– magnitude $(1-\beta_2(t))\cdot v(t)\cdot\alpha_2(t)\cdot y(t)$, allocated by the corporation for conducting transactions (investment) of the corporation at the moment of time t;

– magnitude $a_1(t)\cdot(1-\beta_1(t))\cdot k_d\cdot u(t)\cdot\alpha_1(t)\cdot x(t)$ is the percent payment for investment resources $(1-\beta_1(t))\cdot u(t)\cdot\alpha_1(t)\times \times x(t)$ of the company.

Interaction finishes when the conditions are met:

$$(x(t), y(t))\in M_0, \tag{3}$$

$$(x(t), y(t))\in N_0. \tag{4}$$

where $M_0=\{(x, y):(x, y)\in R^2_+, x>0, y=0\}$, $N_0=\{(x, y): (x, y)\in R^2_+, x=0, y>0)$.

From an economic perspective, these terms are interpreted as follows. Expression (3) corresponds to the state of loss of investment resources (capital) of the corporation, and the investment company increased its capital by the magnitude of the capital of the corporation. Expression (4) corresponds to the loss of the capital of the investment company and the corporation increased its capital by the magnitude of the capital of the investment company. If neither the first, nor the second condition is met, interaction of the investment companies and the corporations continues.

Here arises the question about determining the time of probabilities of loss of capital (investment resources) based on information about primary resources (capitals), currency exchange rate, rate of growth of resources of the investment company and the corporation, interest rates on allocated capital, levels of payable and receivable accounts. The answer lies in the area of the theory of differential quality games [4–7] for interacting objects. To find the preference regions, the differential quality game with two terminal surfaces is solved. The solution lies in determining of sets of preferences of the parties, as well as strategies (control influences) of the parties, by applying which it is possible to receive the outcomes, preferred by each side.

Under this approach, a set of preferences of one party is in its essence a set of loss of capital for the other party. Indeed, preservation of capital is the preferred outcome and its loss is an undesirable outcome for either party of such interaction. However, there may be cases where one of the parties could act in the worst way in relation to the other party, which ultimately brought another party to a loss of capital. In this case, a set of original states of resources of the interaction parties with the property that there are strategies (control influences) of one party, leading the other party to the state of the loss of capital, can be called a set of loss of capital for the other side.

We will note that the initial interaction is not limited to model of the differential game. Similarly, it can be possible to simulate interaction, reflecting the operation of several investment companies, corporations; it is possible to take into account incompleteness of information that companies, corporations, etc. have. That is, it is possible to use the apparatus of differential games for group interaction and for interaction with incomplete information.

In the research we will limit ourselves to consideration of a simple variant of interaction, which allows making qualitative conclusions about the financial state of entities. In the decision the ratio of interaction parameters is taken into account, and possible moment of capital loss by entities of interaction is modeled.

Solution to the problem

For convenience of presentation, subsequently we will "identify" the investment company with player (I), and the corporation – with player (II). Interaction will be considered within the scheme of a positional differential game with complete information [4–7]. Within this scheme, interaction gives rise to two problems – from the point of view of player-ally 1 and from the point of view of player-ally 2. Because of symmetry, it is enough to consider only one of them, for example, from the point of view of player-ally 1. To do this, we will determine pure strategies of player-ally 1. Let $T=[0, L]$ designate temporary segment, i.e. the set, characterizing the region of changing of temporary parameter; L will designate a positive real number.

Definition

A pure strategy of player-ally 1 is function $u: T\cdot [0,1]\times \times[0,1]\rightarrow[0,1]$, putting to the state of information (position) $(t, (x(0), y(0)))$ value $u(t,(x(0), y(0)))$: $0\le u(t,(x(0),y(0)))\le 1$.

The pure strategy of player-ally 1 is a function (rule), putting to the state of information at moment t value $u(t, (x(0), y(0))$ that determines the magnitude of resource (capital) of player 1, which he allocated for "investment" of player 2. In relation to awareness of the player-opponent (in the context of the positional play), no assumptions are made, which is equivalent to the fact that the player-opponent chooses his control influence $u(t)$ based on any information. After determining of strategies in *problem 1*, it is necessary to determine a set of preference for player 1. Bearing in mind that for presentation of the proposed approach it is sufficient to give only a high-quality description, set of preference W_1 of player 1 with be presented as follows.

W_1 is the set of such initial resources $(x(0), y(0))$ of the players, which have the property: for these initial states, there exists the strategy of player 1, which for any implementations of strategies of player 2 at one point of time t "brings" the state of system $(x(t), y(t))$ to the state, in which condition (1) will be satisfied. In this case, player 2 does not have any strategy that can "lead" to the implementation of condition (2) at one of the previous moments of time. The strategy for player 1 that has the specified property is called optimal. Solution of *problem 1* lies in finding a set of preference of player 1 and its optimal strategies. Similarly, the problem is stated from the point of view of player-ally 2. Due to the symmetry of problem statement, it is sufficient to solve only *problem 1*, because *problem 2* is solved is the same way.

Let us assume that for any moment of time t the following conditions are satisfied:

$\alpha_1(t)=\alpha_1;\ \alpha_2(t)=\alpha_2;\ \beta_1(t)=\beta_1;$

$\beta_2(t)=\beta_2;\ r_1(t)=r_1;\ r_2(t)=r_2.$

Let us designate through q_1 and q_2 the following magnitudes:

$q_1=(1-\beta_1)\cdot(a_1+r_1)-1;\ q_2=(1-\beta_2)\cdot(a_2+r_2)-1.$

Four cases are possible:

a) $q_1\geq 0;\ q_2\geq 0;$

b) $q_1<0;\ q_2<0;$

c) $q_1>0;\ q_2\leq 0;$

d) $q_1\leq 0;\ q_2>0.$

In addition, there are various ratios of other interaction parameters, for instance, growth rates α_1, α_2 and other parameters.

Solution of *problem 1* is found with the help of the tools of the theory of differential games with complete information [4–7], which allows finding the solution of the game at various ratios of game parameters. Let us present the solution of the game, i. e. set of preference W_1 and optimal strategies of player 1.

Let us consider case a). In this case, we will obtain:

$$W_1=\{(x(0),\ y(0)):\ (x,y)\in int\,R_+^2,\ y(0)<g^*x(0), \quad (5)$$

where

$$g^*=\{-[q_2*\alpha_2+\alpha_2-q_1*\alpha_1-\alpha_1]/[2q_2*\alpha_2]+$$
$$+\sqrt[2]{\{\{[q_2*\alpha_2+\alpha_2-q_1*\alpha_1]/[2q_2*\alpha_2]\}^2+(q_1*\alpha_1)/(q_2*\alpha_2)\}},$$

where $u_*(x,\ y)=\{1,\ y<g^*x,(x,\ y)\ int\,R_+^2,$ and is not determined, otherwise}.

In cases b) and c) set W_1 is empty.

In case d) and $\alpha_2>\alpha_1+q_1\cdot\alpha_1$ we obtain

$$W_1=\{(x(0),\ y(0)):\ (x(0),\ y(0))\in int\,R_+^2,\ y(0)<f\cdot x(0)\},$$

where

$$f=(q_1\cdot\alpha_1)/(\alpha_2-q_1\cdot\alpha_1-\alpha_1);\ u_*(x,y)=\{1,\ y<f\cdot x,\ (x,y)\in int\,R_+^2,$$

and is not determined, otherwise}.

In case d) and $\alpha_2\leq\alpha_1+q_1\cdot\alpha_1$ we obtain:

$$W_1=int\,R_+^2,\ \ u_*(x,\ y)=\{1,(x,\ y)\in int\,R_+^2,$$

and is not determined, otherwise}.

All cases of ratio of interaction parameters were considered. *Problem 2* from the position of player 2 is solved symmetrically.

As it was already noted, the problem from the position player-ally 2 is solved similarly. And regions of preference from the position player 2 are "adjacent" to the preference regions of player 1. These regions are divided by balance beams, which have the property that if couple of states $(x(0),\ y(0))$ belongs to the balance beam, the players have strategies that allow them to stay on the balance beam for all subsequent points of time. While solving the problems using the proposed game methods, there are balance beams in the space of variables $(x,\ y)$. That is, if interaction starts from these states, the players have strategies that allow them to remain on the balance beam. This means that at assigned $(x(0),\ y(0))$, it is possible to find the ratio on the parameters of interaction. In this case, couple $(x(\mathrm{t}),\ y(\mathrm{t}))$ will be on the balance beam.

If initial states (resources) are not located on the balanced interaction beam, it is possible to try to modify communication parameters for initial resources to be on the balance beam. This will enable the parties to continue their interaction as long as you want.

It should be noted that there may be situations when interaction parameters changed. Then it is possible to carry out the stated procedure at new parameters and find new optimum strategies for interaction between the parties, i. e. the proposed scheme of control of interaction of the vertically integrated company and its counterparty is adaptive.

Comment 1. The "stronger" currency affects "an increase" in preference zones (comparison by inclusion of sets) and "a decrease" of investor's risk zones from the economy with a "stronger" currency and vice versa. This means that an investor with a "weaker" currency should leave the areas of financial resources, which are subject to risk of losing capital due to "weakening" of currency of the investor-country.

Comment 2. Considered example of the simplest interaction allows making the following conclusion about the fact that in the space of initial resources, there are preference areas for players. Therefore, if resources are in the preference area of any player, it is disadvantageous for this player to avoid interaction with another player. Player 2 is supposed to be able to change the ratio of resources in the absence of interaction as a result of autonomous operation. For example, this is possible to implement by using the advantage of technology. And then, after starting interaction, one may gain the advantage in this interaction and "bring" the other player to loss of capital.

5. Computational experiment on the choice of strategy for mutual financing

Based on the proposed model of continuous mutual investment, DSS software module "SSDMI" was implemented (Fig. 1).

Module "SSDMI" can be used both as an independent software product and as an auxiliary unit of decision support system "DMSSCIS", which, in particular, allows assessment of investment risks in information security systems of large enterprises [19, 20].

Computational experiments were conducted (Fig. 2, 3). Data from the State Statistics Committee of Ukraine over the period from 2011 to 2016 were taken as source data. During analysis of operation of "SSDMI", correctness of the algorithm implementation was monitored.

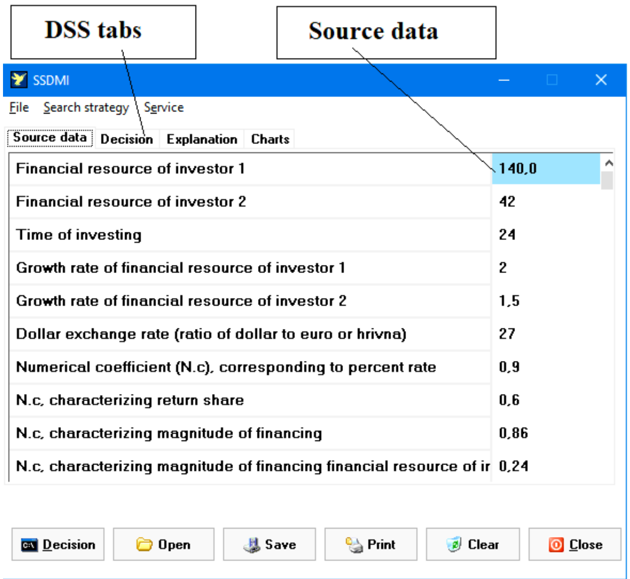

Fig. 1. General outlay of the software module "SSDMI"

Fig. 2 shows the form for interpretation of the results of decision making support, provided by DSS "SSDMI". X axis in the graph means "USD, million". Y axis means "UAH, million". Tangent of the slope angle is equal to "3.5". That is, the balance beam is determined by ratio value «$y=g^{*}\cdot x$», $g^{*}=3.5$. The area, highlighted in blue color, corresponds to W_1. The area, highlighted in light yellow, corresponds to W_2.

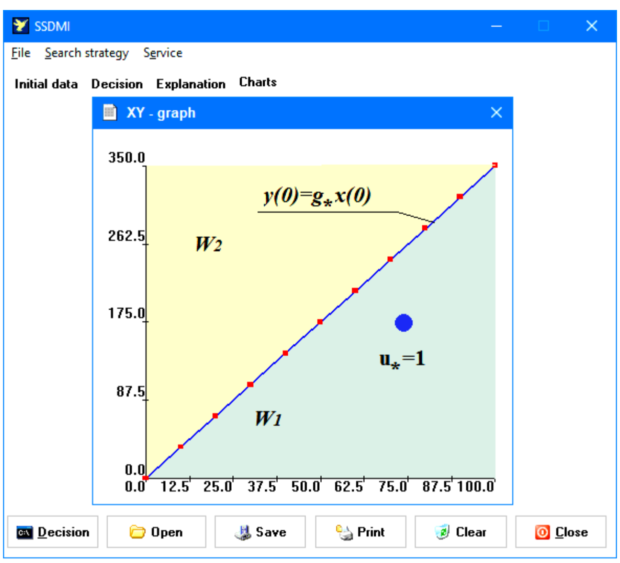

Fig. 2. General view of tab of graphic interpretation of results of DSS operation on mutual investment

Fig. 3 shows results of DSS operation for modeling investments at a particular enterprise of the IT sector. The trajectory of the investors' motion is shown in a red line with blue markers in W_1 area. In the graph, it is accepted: x – financial resource of investor 1; y – financial resource of investor 2. The graph is plotted in the course of computational experiment for the following set of states: $(x(0),\ y(0))=(1.5,\ 4.77)$; $(x(1),\ y(1))=(2.0,\ 4.583)$; $(x(2),\ y(2))=(2.5,\ 4.33)$; $(x(3),\ y(3))=(3.0,\ 4.0)$; $(x(4),\ y(4))=(3.5,\ 3.57)$; $(x(5),\ y(5))=(4.0,\ 3.0)$.

In Fig. 3, the balance beam (shown in blue with red handles) is the same as in the first graph, i.e. «$y=g^{*}\cdot x$», $g^{*}=3.5$.

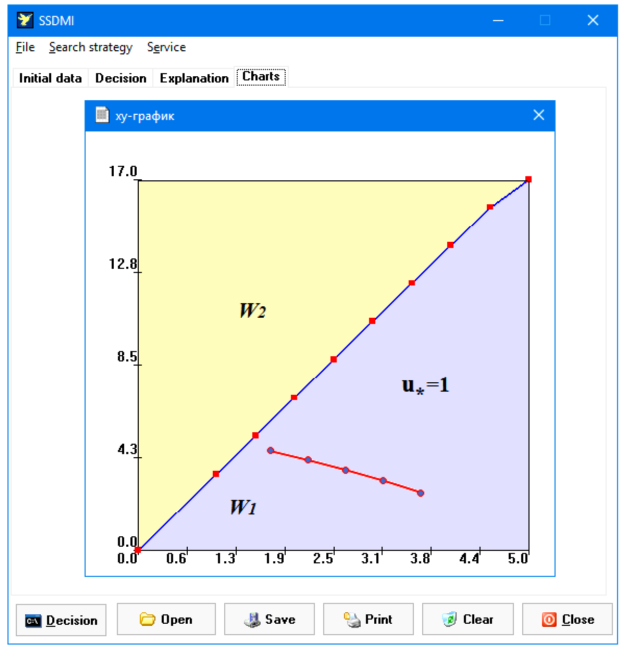

Fig. 3. Results of DSS operation for selection of strategies for mutual investment at an enterprise in IT sector

The obtained results demonstrate effectiveness of the proposed approach. During testing of program "SSDMI", correctness of the obtained results was established. Approbation of DSS "SSDMI" was also executed for actual investment projects in IT sector in the city of Kyiv.

6. Discussion of results of computational experiment

The considered procedure of interaction is the process of prediction of investment outcomes. It is natural, that in this case, the prediction data, obtained with the help of DSS did not always coincide with the actual data. We will note that this is an objective reality and it is impossible to get rid of it. This is a definite drawback of the approach, outlined in this article. We can only strive to reduce discrepancies, in particular to improve the tools of prediction of investment processes due to information technologies (intellectual data analysis, DSS, ES, etc.). If these tools are reasonably supplemented by the IT, mentioned above, it will be regarded as an attempt to make the investment process more efficient. The considered approach allows us to do this because it gives the possibility to select variable parameters of the investment process so that it could become balanced. Results of the computational experiment and practical data of evaluation of investment projects were compared to the results, described in the papers [1, 2, 12, 19, 21]. In the course of comparative analysis, it was determined that the proposed tools allow participants of the investment process to substantially improve indicators of performance and predictability of their activities.

Further prospects of developments of this study include transfer of accumulated experience to Android platform when designing DSS. This will increase mobility in making decision on mutual investment.

7. Conclusions

1. The procedure of interaction of investors on the micro- and macro- level, which allows predicting investment

outcomes, was considered. For this purpose, the model, within which there are investment management strategies at different ratios of parameters of the investment process, was proposed Application of the model in decision support systems, in contrast to the existing models, gives specific recommendations in the process of making management decisions in the investment process. The essence of the model lies in the fact that it makes it possible to determine the optimal investment strategy and to predict the outcome of the investment process at any ratios of parameters of the investment process. For the case when a prediction is not beneficial for investors, we propose using the algorithm of adjustment of the investment process parameters so that the parties could reach a result, acceptable for them. From the mathematical point of view, the model is based on solution of a bilinear differential quality game with several terminal surfaces. A special feature of this differential game is that the right part of the system of differential equations is bilinear functions with arbitrary coefficients.

2. Software module of DSS "SSDMI", which implements the proposed model based on application of methods of the theory of differential games, was described. A new class of bilinear differential games, which allowed us to describe adequately the investment process, was considered. DSS enables us to reduce divergence of prediction data from the actual return on investment. It is shown that if the proposed DSS tools are reasonably supplemented, this will be an attempt to make the investment process more efficient. The computational experiment was conducted, which proved workability of the model and software program "SSDMI", specifically for investment projects in information technologies, information and communication and cyber security systems.

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DEVELOPMENT OF THE METHOD FOR DETERMINING OPTIMAL PARAMETERS OF THE PROCESS OF DISPLACEMENT OF TECHNOLOGICAL OBJECTS

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Робота відноситься до області оптимізації технологічних процесів, зокрема, до питань пошуку найкращого управління для систем переміщення. В рамках запропонованого методу визначається внесок процесу розгону і процесу рівномірного переміщення в формування доданої цінності досліджуваної операції. Вихід в режим оптимального управління забезпечується спеціальною процедурою визначення області, близької до точки глобального оптимуму

Ключові слова: пошук оптимального управління, оптимізація процесу переміщення, двоетапна оптимізація процесу переміщення

Работа относится к области оптимизации технологических процессов, в частности, к вопросам поиска наилучшего управления для систем перемещения. В рамках предложенного метода определяется вклад процесса разгона и процесса равномерного перемещения в формирование добавленной ценности исследуемой операции. Выход в режим оптимального управления обеспечивается специальной процедурой определения области, близкой к точке глобального оптимума

Ключевые слова: поиск оптимального управления, оптимизация процесса перемещения, двухэтапная оптимизация процесса перемещения

1. Introduction

Targeted improvement of operational efficiency of an industrial enterprise is possible only in the case when all its resource-intensive technological processes are optimized. In this case, optimization criteria of the managed systems must be systematically substantiated, inter-coordinated, and have to ensure maximization of financial capacity for the owner of results of operational processes (super-system).

Despite the fact that such a statement of the optimization task seems obvious, at present, managed systems integrate as optimization criteria a variety of indicators that are subjectively defined as the criteria of optimization [1]. Such indicators turn managed systems into extreme systems rather than making them optimal [2].

Among the many classes of managed systems, a special place is taken by displacement systems. The systems of this class are extremely diverse and comprise hoisting-and-transporting mechanisms [3], conveyor mechanisms for continuous transportation [4], motor transport systems [5]. They also include systems for transporting liquid and gaseous products. All these objects perform a function of the connecting link between the systems of a transformative class and the buffering systems.

A special feature of such objects is that the choice of the best parameters of a technological process is affected by

ABSTRACT AND REFERENCES

CONTROL PROCESSES

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DESIGN OF THE SYSTEM TO CONTROL A VIBRATORY MACHINE FOR MIXING LOOSE MATERIALS (p. 4-13)

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Based on the analysis of special features in the implementation of process of mixing a loose material, we have proven a prospect of using vibratory machines. The application of vibratory machines for mixing loose materials makes it possible to increase performance efficiency of the machine, reduce its energy consumption and improve quality of the obtained mixture. Intensive oscillatory motion of controlling elements of the vibratory machine contributes to the creation of a circulating transportation of mixture in the processing zone and ensures destruction of coagulated structures of the treated material.

To ensure the highly-dynamic state during treatment of a material, regardless of the physical-mechanical properties of raw materials and the degree of its loading, we designed a system of control over operational parameters of the vibratory machine.

The designed system improves control systems based on the adapted vibration drive that may enable a change in the arrangement of its unbalanced masses during operation of the vibratory machine. However, the shortcoming of these systems is the assessment of amplitude-frequency characteristics of the machine only. In contrast, in the proposed system, the monitoring unit runs a comprehensive analysis of kinematic and speed characteristics of both the machine and the dynamic state of the treated material.

The proposed control system includes the unit for active analysis of the dynamic state of oscillatory system and the control unit over a drive mechanism of the vibratory machine. Functional interaction between specified units, depending on the type of a raw material, ensures independent adaptation of the vibratory machine to the technologically optimal parameters of its work.

By using designed control system, we obtained operational parameters for the kinematic and speed indicators of the vibratory machine for preparing a premix, which ensure high homogeneity of the resulting mixture at minimum energy consumption for its preparation. Specifically, at angular velocity of drive shaft ω=110–120 rad·s-1and oscillation amplitude A=2.0–2.2 mm, homogeneity of the resulting mixture of premix is 96–98 %. Total energy consumption for these indicators is equal to 1,250 W·h.

Keywords: effect of vibration on the process of mixing, loose material, control system, optimal operational parameters of vibratory machine.

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DEVELOPMENT OF AUTOMOTIVE COMPUTER SYSTEMS BASED ON THE VIRTUALIZATION OF TRANSPORTATION PROCESSES MANAGEMENT (p. 14-25)

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We proposed the concept of creating automotive computer systems based on the virtualization of transportation processes management. It was proven that the implementation of basic principles and rules of the virtual management of the enterprises of a transportation services market makes it posssible to improve efficiency of operation of transportation and road enterprises of Ukraine. A new approach is proposed to the creation of a unified informational space of the market of transportation services based on using cloud computing. A special feature of such a synergistic approach to the informational development of the market of transportation services is zero capital investment on their implementation and introduction to the transportation and traffic organizations. We investigated interactive monitoring of the chosen route. An artificial neural network for estimating a route is designed. A transportation information matrix is proposed to use a source of information about state of the routes of respective transfer, both of cargo and passengers, in contrast to conventional transportation processes.

Keywords: virtual management, transportation services, unified information space, synergetics, automobile computer systems, interactive monitoring, road transport portal.

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INTEGRATED APPROACH TO THE DEVELOPMENT OF THE EFFECTIVENESS FUNCTION OF QUALITY CONTROL OF METAL PRODUCTS (p. 16-34)

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The principle of development of the integrated effectiveness function of quality control of metal products is proposed. A characteristic feature of this function is that it combines different criteria, expressed through the coefficients of technological effectiveness, economic and legal capacity. Within this framework, the approach to formalization of the description, which can be used to search for optimum control of the metallurgical duplex process on the basis of the universal mathematical description of both process stages is proposed. This approach is very convenient, since it allows using the same mathematical model, but with different variables when searching for optimum control. The control of the induction duplex process, chosen on the basis of this mathematical description, allows maximizing the product quality, and, accordingly, the coefficient of technological effectiveness included in the description of the integrated effectiveness function of quality control of metal products.

It is shown that the greatest uncertainty is present in the assessment of the legal capacity associated with the possibilities of legal regulation as a mechanism of promotion of Ukrainian metal products to the European market. However, despite the difficulty of evaluating the coefficients included in the description of the integrated quality control effectiveness function, at the conceptual level it can be considered reasonable. In this case, this function can be considered as an analog of the risk function and used to select a control strategy based on the statistical game theory.

Keywords: induction duplex process, heat treatment, quality control of metal products, legal regulation, control effectiveness function.

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DEVELOPMENT OF THE DECISION MAKING SUPPORT SYSTEM TO CONTROL A PROCEDURE OF FINANCIAL INVESTMENT (p. 35-41)

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The model of continuous control of the procedure of mutual financial investment for the decision support system was proposed. The model makes it possible to optimize finding multi-variant strategies in mutual financial investment of projects. From the mathematical point of view, this model is based on solution of a bilinear differential quality game with multiple terminal surfaces. A specific feature of this game is that the right part of the system of differential equations is bilinear functions with arbitrary coefficients.

The model is implemented in the high-level language C++ in the software product “Decision support system for mutual investment – SSDMI”, which was tested in a number of investment projects. The model allows solving the problem of improvement of effectiveness of the procedure of mutual financial investment for participants at different ratios of interaction parameters. There can be found a condition, under which the procedure of mutual financial investments

becomes beneficial to all participants. Apparatus of the theory of differential games was proposed as a toolkit for development of an effective strategy for mutual financial investment. In the framework of this research, the process of interaction between an investor from one country and its counterparty from another country is explored. The selected approach enables us to identify the areas of possible initial states of resources (financial capitals) of interacting objects. The objects are supposed to have the following property: if interaction starts from these initial states, there can be a loss of financial capital either by one interacting party or the other at one of the moments of time.

Solution to the game lies in the identification of sets of preference of the parties and the strategies (control actions) of the parties, by applying which it is possible to obtain the outcomes, preferable for each side. Based on the findings, conclusions were made and recommendations were given to investors in terms of their subsequent actions with a view to obtaining the best possible outcome in terms of financial investment and a decrease in investment risks.

Keywords: decision support system, investing, financial capital, selection of strategy, game theory.

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DEVELOPMENT OF THE METHOD FOR DETERMINING OPTIMAL PARAMETERS OF THE PROCESS OF DISPLACEMENT OF TECHNOLOGICAL OBJECTS (p. 41-48)

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The optimization of technological processes is the only tool that can ensure maximization of financial resources of the owner of an enterprise. The most numerous class of managed systems is the systems of displacement.

It is believed that finding an optimum of the displacement process can be implemented using the methods of dynamic programming. However, in this case, the search process is carried out under the assumption that an increase in the displacement velocity has no effect on the magnitude of wear of the technological mechanism of a displacement system. In this case, parameters of the acceleration and the established process of displacement are determined employing different criteria for the quality of control.

In contrast to the conventional approach, within the framework of present study, a two-stage operational displacement process is optimized based on a single criterion of the efficiency of resource use. However, the optimization model of a displacement process is essentially non-linear. Classical methods of searching for a global optimum under such conditions imply unnecessarily long work of technological equipment under non-optimal modes.

The idea of the method is to significantly narrow the region of a two-parametric search optimization using a one-parametric search for local extrema of the sub-processes of acceleration and uniform displacement and to maximally close approach the global optimum at its first step.

The research has shown that the narrowing of the region of a two-parametric search optimization of the process of displacement can be ensured through preliminary four-stage single-parametric search for local extrema for the sub-processes of acceleration and the process of uniform displacement. Within the range of the first and second stages of search for local minima of the sub-processes costs we determine initial conditions in the search for local maxima of the efficiency of displacement sub-processes. The coordinates of the found extrema enable determining a starting point of the search optimization and limit the search region.

The proposed method significantly reduces the dimensions of region of search optimization (by seven times in the considered example) and reduces the number of steps in the search optimization by an order of magnitude.

Therefore, the proposed practical method of searching for the optimal trajectory of control is robust in its essence.

Keywords: optimal trajectory, practical optimization method, two-stage optimization, search optimization.

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EVALUATION OF THE RAILRWAY TRAFFIC SAFETY LEVEL USING THE ADDITIVE RESULTANT INDICATOR (p. 48-57)

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A comprehensive approach to determining the level of safety of train traffic on the objects of the railway infrastructure was proposed. This approach involves taking into account a wide range of factors of influence when determining the safety level. These factors include technical means, personnel management, production practice and investments to the traffic safety. Each factor is characterized by its indicators. The total number of indicators is twelve. They have different dimensionality. In this case, the problem of complex estimation is considered as a multicriteria optimization problem. Solution to this problem is proposed using an additive resultant indicator. It was proposed to introduce a term that determines quality of the safe operation of the sector dealing with transportation of goods and passengers: the level of safety of the transportation process at an infrastructure object. As a criterion for assessing the traffic safety, a resultant additive indicator was formed which determines the level of traffic safety of the train traffic at an infrastructure object. This indicator represents the sum of monotonically growing positive additive functions each of which has its weight (weight factor). The resultant indicator is dimensionless and does not exceed the value of 1. In determining the weight factors, the method of expert estimates is used.

The proposed method of assessment of traffic safety will provide analysis of the situation at the railway range at a higher quality level. It is possible to identify more dangerous infrastructure objects that affect the overall level of safety of the railway net. Application of this method will optimize allocation of resources to ensure traffic safety while adhering to its permissible level. The method can be used in the design of infrastructure projects to determine their level of safety in the process of transportation of goods and passengers.

Keywords: traffic safety, method of assessing the level of traffic safety, complex indicator.

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DEVELOPMENT OF THE SYSTEM FOR PREDICTION OF SECURITY STATE OF AN ENTERPRISE USING SEMANTIC–FRAME FUZZY MODELS OF KNOWLEDGE BASE (58-65)

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The system based on results of prediction of technical and technological potential was proposed; it provided clear current values of indicators of the enterprise's operation, properties and permissible restrictions of these properties. It was proved that the proposed system has a special purpose and consists of units of classes of indicators and the base of the facts of individual instances of classes, and can be used for the implementation of prediction problems in any industry.

As a result of modeling, it was found that introduction of the prediction unit into a system allows us more accurately and objectively to consider and evaluate a whole range of indicators of the enterprise's operation. The proposed prediction system calculated approximated prospective value of the indicator of the state of technical and technological potential of an enterprise in time, which greatly affects probability of bankruptcy of an enterprise. It is appropriate to use the prediction system for complex processes with fuzzy logic, when there is no simple mathematical model and expert knowledge can be formulated without fuzzy logic only in linguistic form. This proves that the proposed system can be used for prediction of all other potential of an enterprise that also influence probability of bankruptcy of an enterprise.

Keywords: semantics, frame, knowledge models, knowledge base, output machine, regressive dynamic models, prediction, security, potential, expert knowledge, taxonomy.

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A PROCEDURE FOR OPTIMIZATION OF ENERGY SAVING AT HIGHER EDUCATIONAL INSTITUTIONS (p. 65-75)

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A base of the methodology of optimization of an energy saving system in higher educational institutions of Ukraine is maintenance of a given level of thermal comfort. Its aim is the increase of HEI efficiency. The methodology of optimization of an energy saving system in higher educational establishments should be realized in two stages. At the first stage, we should carry out an energy audit of premises. The audit is a compilation of a balance of heat loss and heat supply of each HEI premise. At the second stage, we carry out optimization of energy saving and making managerial decision on loading of premises. We carry out optimization of energy saving by means of a model of optimal control of a thermal mode of premises with minimization of energy consumption for heating and energy loss.

The given methodology is substantiated and correct for estimation of potential efficiency of HEI premises and making up an energy-efficient plan for use of an auditorium during a heating period. We carried out a pilot testing of the energy saving system optimization project at Kyiv National University of Technology and Design. The testing confirmed a high level of its energy efficiency.

Keywords: heat supply, heat loss, ABC-XYZ-analysis, game theory, optimal mode of heat consumption, higher educational institutions.

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