INTELLECTUAL INFORMATION SUPPORT OF BRANCH ENTERPRISE EXECUTIVES' DECISION MAKING PROCESSES

Aleksey Voloshyn, Bogdan Mysnyk, Vitaliy Snytyuk

Abstract: *The optimization problem of functioning of the producing similar products enterprise is considered. For its solution proposed multiagent technology, the use of which will make informed decisions about the expansion of production, reduction, and so branching. Models of the enterprise functioning in a competitive environment are constructed.*

Keywords: *enterprise, interaction, models, multiagent technology.*

ACM Classification Keywords: *I.2.11 Distributed Artificial Intelligence – Multiagent Systems.*

Introduction

Current economic realities characterized by even slowly but steadily growing development of small and medium enterprises. Information technologies and its dominant influence on decision-making processes lead to the emergence and functioning of an increasing number of e-business enterprises. At a time when on the market are dominated major natural and artificial monopolies, and are a growing number of small businesses, for which by the effective organization of production continues to be a high rate of profit. But for all unchanging factors values that affect on enterprises activities, this rate has been steadily decreasing, due to the saturation of the market. There is the problem of businessmen for the development or production cuts. And it is particularly relevant to the industry, which, as you know, is the set of firms producing similar (identical) products. Today it is the production of doors, plastic windows, and provision of buildings repair, their construction, e-commerce appliances and more.

It is known, progress in any sphere of human activity is realized as a result of an idea or need. And it is in business at an early stage of the life cycle of business activity, these two concepts are closely integrated into each other. Stage of functioning has more realistic aspects. It is based on just the need, need for profit to pay salaries, social security, implementation of environmental activities and more. It is important that at this stage of accumulating and developing capital assets created some capital. Due to various circumstances, any enterprise and its manager is faced with the dilemma of liquidation or development. The solution of this problem stems from the necessity but the corresponding areas, mainly based on the ideas.

Analysis of recent research and results

The use of multiagent systems does not total also 20 years old. The basic idea posited in its functioning, is the implementation of autonomous software agents that are able to accept the situation, make decisions and interact with their own kind. Thus, the solution of any complex problem emerges in an evolutionary way by agents that continuously compete and cooperate with one another.

Multiagent technology applied in such industries and firms in UK to manage: tanker fleet (Tankers International, London); corporate taxi fleet (Addison Lee, London); fleet of freight cars (Gist, Manchester), the provision of vehicles for hire (Avis, Liverpool); in solution of problems related to: aerospace studies, intelligent transportation, smart factories functioning mobile teams of rescuers, working railroad and logistics.

Multiagent technologies based on the principles of self-organization and evolution of behavior characteristic of living systems as ant colonies and swarms of bees.

Multiagent technology capable to solving problems of planning and resource optimization, pattern recognition, comprehension of texts under the scheme: initialize the system load model monitoring the current situation analysis of the problem situation refine your monitoring of resource allocation plans expected result.

Unlike classical systems, the MAC is a large network of small agents operations are performed in parallel with the evolution of the place and the conditions for the development of [Gurevich, 2005].

It is important to note the complexity and dynamics of decision making in the management of production in real time. And with such problems multiagent technology can prove itself best [Ivashchenko, 2011].

Author [Skobelev, 2003] provides multiagent systems for timely processing of information and operational models of network requirements and capabilities. Competing elements of each of them in operation are capable to find optimal solutions. In [Masloboev, 2011] proposed multiagent information technology support decision making in the management of quality educational services for regional research and education complex, designed simulation model of quality management education, where agents are "student" and "teacher".

There are researches where for simulation of industrial enterprises activities applied the ideas and principles of "artificial life" by using neural network technologies to train agents and providing them with the properties of memory and prediction [Snytyuk, 2010].

Multiagent systems built and to the development of telecommunications management, where agents are companies, competitors, some state participants, agents of the state policy in the field of telecommunications, local government agents. The advantages of this multiagent technology are the effectiveness of strategic management by increasing the validity of decisions, taking into account a number of factors, and the analysis of different scenarios of interaction of the telecommunications market participants.

Formalized statement of the problem and its solution

How can multiagent technologies help to solve the problem of optimizing the life cycle processes of the industry? As these enterprises produce the same product, then we consider two cases:

- Products durable, resulting in market saturation;
- Products that have a limited useful life, requiring replacement, and the market demands constant with minor fluctuations the number of goods in time.

Problem being considered in the paper is to maximize the efficiency of the enterprise sector, defined range of tasks, production structure and management strategy that consists in allocating resources [Voloshyn, 2013].

Consider the features of the first case of production. Suppose that in a particular area, there is a need for products P, and $|P| = N$, but after a long time the product needs replacement or repair, so $|P| = N + \delta$, where δ - some positive integer. It can be argued that the required number of products that must stand up for the first time and the number of consumer products that must be replaced are values that depend on time, i.e. $N = N(t), \delta = \delta(t)$, with a monotonous no increasing function $N(t)$ and $\delta(t)$ - monotone no decreasing function. Functions $N(t)$ and $\delta(t)$ can be partially or fully known to producers, consumers and analysts. In addition, it is possible the case when only known expert assumptions about their structure and parameters. So for the moment t, the number of products to market saturation is $N(t)+\delta(t)$.

Assume that the products P produced by M enterprises. Each of them can be represented by an agent acting for a certain application $V_i, i=\overline{1,M}$. The result of the program is a recommendation for a decision maker, or directly the solution. We divide the time interval enterprise operation (T) at intervals $T=\{t_0<t_1<...<t_k<...\}$. We describe the essence of the points in time $t_i, i=\overline{1,L}$, where L - integer or infinity.

Each company will present how a certain system S. Operation of the system is the continuous-discrete process defined by the function

$$F(t)=\begin{cases} f_1(t),\ t\in[t_0,t_1], \\ f_2(t),\ t\in[t_1,t_2], \\ \dots\dots\dots\dots, \\ f_k(t),\ t\in[t_{k-1},t_k], \\ \dots\dots\dots\dots\ . \end{cases}$$

Functions $f_i(t)$ determines the efficiency of the system: profit, cost of production, capital-like. Transitions $f_i(t)\to f_{i+1}(t)$ occur as a result of decisions taken at the times t_i. Determine which factors influence the occurrence of such values t_i. To this consider the system S as part of a higher level of hierarchy, interacting with it, and makes an impact.

Let Ω is the system of higher hierarchy level. There is an interaction between S and Ω, which is expressed in entering in S the material flows (H), power (E), information (I), finance (U), human resources (R) and in production (P) and data (D) coming in Ω from S (Fig. 1). Since all systems $S_i, i=\overline{1,M},$ perform the following exchange with Ω, it is obvious that there are implications $S_i\to\Omega\to S_j,\ S_j\to\Omega\to S_i,\ i\neq j.$ Note that each implication $G_{ij}:S_i\to S_j$ has a different quantitative and qualitative features. |This interchange is done on the already mentioned seven levels. There is an implication $\Omega\to S_j=S_j^{in}(H_j,E_j,I_j,U_j,R_j),$ where $S_j^{in}(*)$ – incoming flows of system S_j. By system S_j performed implication $S_j^{in}(*)\to S_j^{out}(P_j,D_j)$ and the result is output to the system Ω. Thus, there is a chain of implications

$$\Omega\to S_j^{in}(H_j,E_j,I_j,U_j,R_j)\to S_j^{out}(P_j,D_j)\to\Omega,\ \forall j=\overline{1,M}. \quad (1)$$

But implementation of implications (1) takes time and during that time, changing the system Ω. In addition, the transformation (1) is closed, which can be represented formally as follows:

$$\begin{gathered} \Omega_{in}^{i}\to\Omega_{out}^{i}, \\ \Omega_{in}^{i+1}=V(\Omega_{out}^{i})=V((P_j,D_j),\ \forall j=\overline{1,M}). \end{gathered} \quad (2)$$

Expressions (2) indicate that the system Ω is constantly changing, the main influence on it realize the activity results S_j in a complex operation, often obtained by transformation V finance or new information. This, in turn, determines the performance of transformation (1). Considering (1) and (2), we can conclude that the interaction of the system Ω is carried out with each S_j and systems S_j of each other. As a result are changes in the input flows next (s) period (s) of time occurred. Therefore, we assume that there comes a time t_i when $\exists S_j$, or in what comes $H_j \vee E_j \vee I_j \vee U_j \vee R_j$, or from which is obtained $P_j \vee D_j$, with this time $t_i > t_{i-1}$ and it is the minimum $\forall S_j$, $j = \overline{1, M}$.

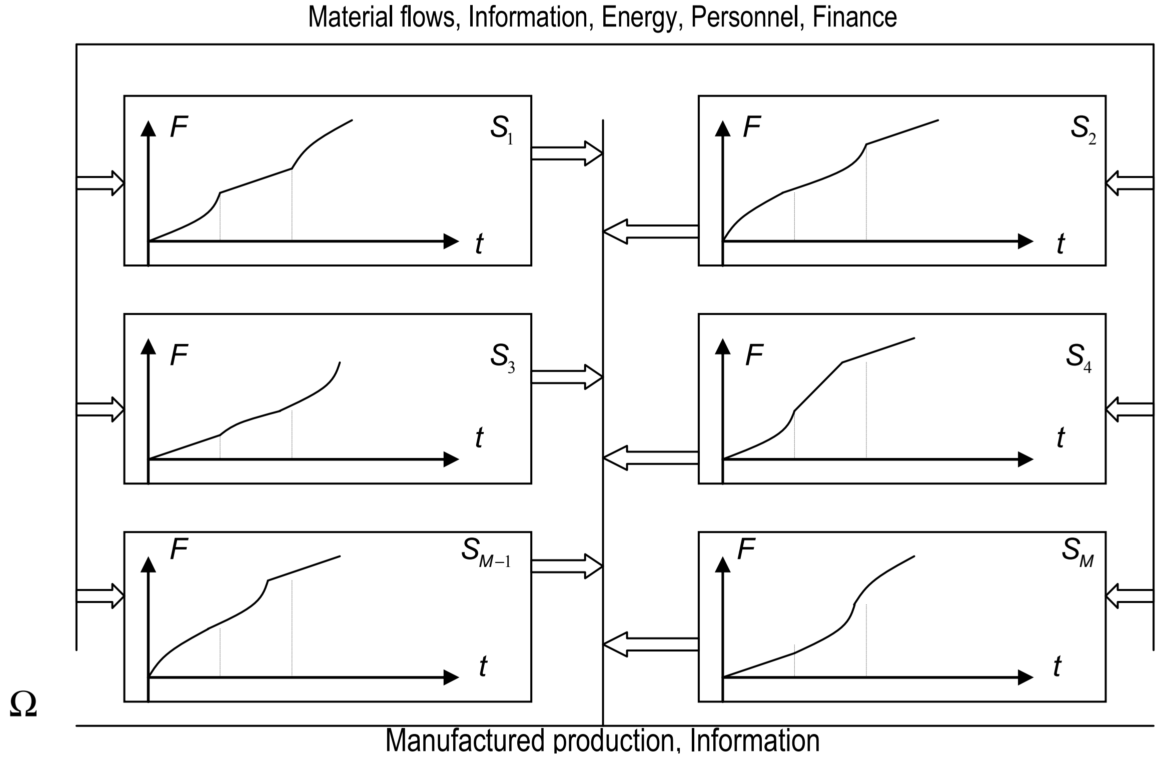

Figure 1. Companies interaction as multiagent technology

In Figure 1 also shows how to change the function $f_i(t)$ at different time intervals. In particular, it can be regarded as characteristic number of products, as evidenced by the monotony of imprinted features.

Thus, multiagent system will take into account information from the outside at times t_i, $i = \overline{0, L}$, which will allow it to carry out adjustment of the elements of production.

Functioning features of multiagent system

Obviously, the simulation is done in the interest of an enterprise. We assume that firms operate in the market industry for a long time. Initial time t_0 of modeling and analysis of the real situation is known. For the moment t_0 initialization of multiagent system is performed. In practice this means setting the values of the states as well system Ω as systems S_j that are viewed as agents. The basic parameters of the systems S_j are:

- Number of raw materials in stock;
- Number of units that may be made with this material;

- The time at which all other things being equal need for a manufacturing unit, or a certain number of units by parallel production;
- The value of fixed assets;
- Number of employees;
- The cost of production;
- Other.

For the system Ω main features are:

- Market demand in a number of products;
- Legal restrictions;
- The financial situation of the company (the amount of money in the account);
- Payables and liabilities.

Obviously, these indicators and characteristics of the whole range are not limited, but the scope of this paper does not allow carrying out them a full recalculation also because of the characteristics of each industry.

After initializing the values of key indicators occurs the process of modeling, which is done loading models (agents). These models reflect indicator of activity efficiency for systems S_j, each performance indicator is the criterion of the system S_j performance of one its functions. The construction of such functions is based on retrospective data. In addition to assessment of the actual state (at the time) this functions allow you to analyze situations "and if A, then ..." in the future. Obviously, the best option simulation corresponds to the absence of critical situations. But in the multiagent system occurrence of any such events should be reflected in the knowledge base along with the production rules of appropriate actions. The occurrence of such extreme events corresponds to one of the points t_i in time of decision making.

The next step after the initialization state enterprises need to make a boot a model of their operation. Here are the main components of this model and define the features of its use. Assume that in the interval (t_{k-1}, t_k) the functioning each of enterprises will be continuous. Then the general model is as follows:

$$\begin{gathered} f_k^{ij}(t),\ k=\overline{1,L},\ i=\overline{1,W},\ j=\overline{1,V}, \\ if\ t=t_k+\delta, \text{then the transition } f_k^{ij}(t)\to f_{k+1}^{ij}(t), \end{gathered} \tag{3}$$

where k - number of time period, i - number of the enterprise, j - number of functions (efficiency indicators), δ - small enough positive number. Functions $f_k^{ij}(t)$ may have a different specification. If $f_k^{ij}(t)$, for example, is the number of issued goods, then $f_k^{ij}(t)=const \vee 0,5t+7 \vee 2t^2+3t+1$... In the first case, the number of produced goods is constant, in the second - a linear growth, in the third - is the quadratic dependence and $t\in(t_{k-1},t_k)$.

Assuming that produced goods are sent to the warehouse and from there comes to consumers and the storehouse has a limited capacity, the subset of models describing the activities of the enterprise is as follows:

$$f_k^{ij}(t) = kt,\ k > 0\ (offer),$$
$$f_k^{ij+1}(t) = lt,\ l > 0\ \ (demand),$$
$$f_k^{ij+2}(t) = (k - l)t\ \ (number\ of\ products\ in\ storehouse).$$

For example: $f_k^{ij}(t) = 3t,\ f_k^{ij+1}(t) = 2t,\ f_k^{ij+2}(t) = t$ (Figure 2a).

If the demand is decreasing then models are as follows:

$$f_k^{ij}(t) = kt,\ k > 0\ (offer),$$
$$f_k^{ij+1}(t) = lt + a,\ l < 0\ \ (demand),$$
$$f_k^{ij+2}(t) = (k - l)t - a\ (number\ of\ products\ in\ storehouse).$$

For example: $f_k^{ij}(t) = 3t,\ f_k^{ij+1}(t) = -2t + 16,\ f_k^{ij+2}(t) = 5t - 16$ (Figure 2b).

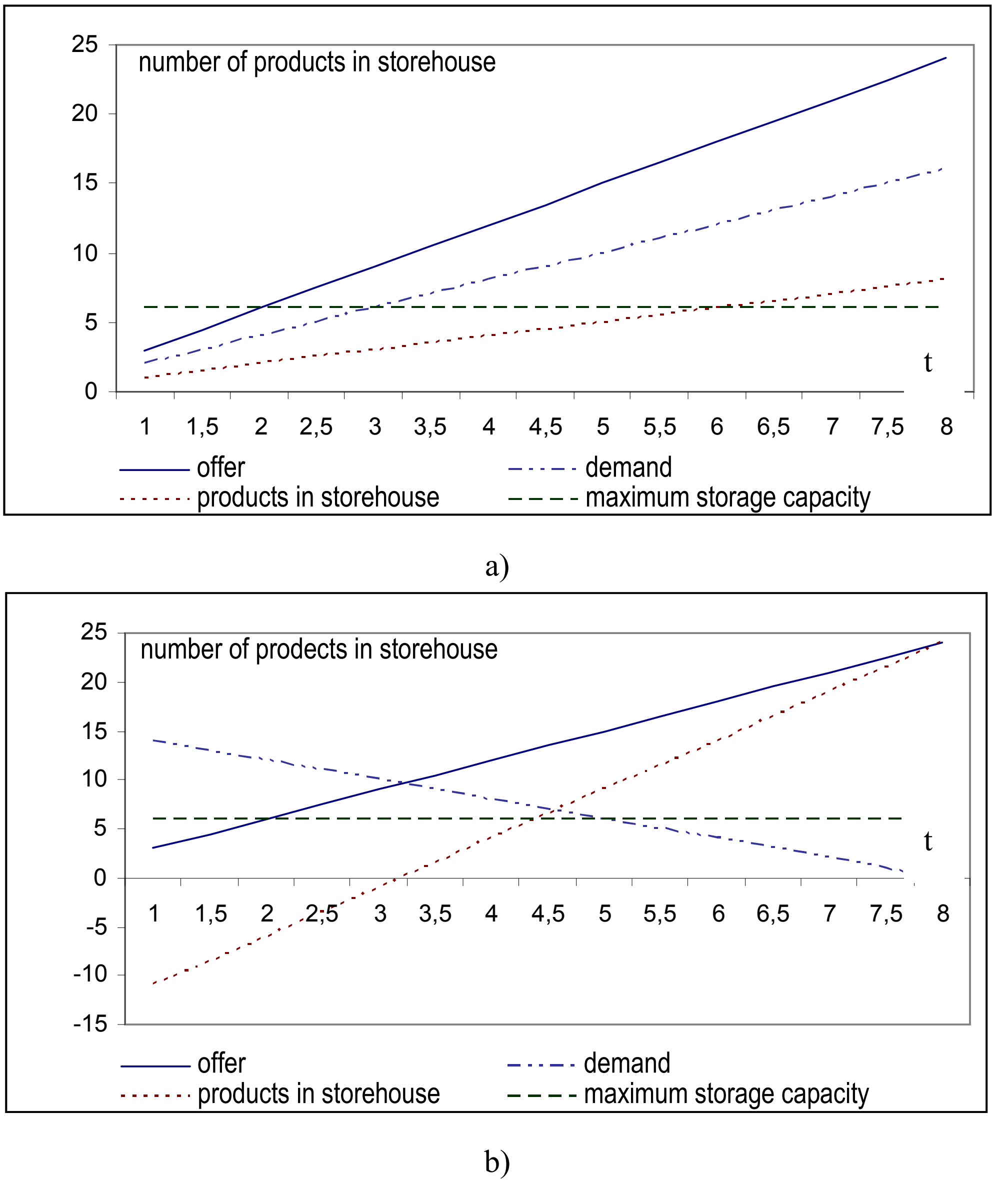

Figure 2. Enterprise activity and features dynamics

It is obvious that in the cases in:

- Figure 2a - at time $t^* = 6$ and at time $t^* = 4,4$;
- Figure 2b - number of products in storehouse up to the maximum capacity of staff,

it is necessary to make a decision that $\exists k \in N : t^* = t_k$. It is similarly constructed as other models and defined decision points. Note that for many models there will be dependence

$$f_k^{ij}(t) = G_{k-1}^{ii\,j}(f_{k-1}^{ii\,j}(t)), \tag{4}$$

indicating that the dependence of certain features of i th enterprise on k th time interval of the same function of ii th on $(k-1)^{th}$ time interval, $ii \neq i$. Without loss of generality, we consider that the exchange of information between companies, enterprises and the environment about the features and results of activity occurs in moments time t_k. Dependence (4) for most companies allows generalization:

$$f_k^{ij}(t) = G_{k-1}^{\Lambda(i)\,j}(f_{k-1}^{\Lambda(i)\,j}(t)), \tag{5}$$

where $\Lambda(i)$ is a set of enterprises, and j th function of which affect on j th function of i th enterprise. Expression (5) indicates that, as j th function of i th enterprise depends on the values of j th function of enterprises from the set $\Lambda(i)$ of companies in $(k-1)^{th}$ time interval.

Consider a number of models on which implemented the functioning of enterprises. In particular:

$$f_k^{ij}(t) = G_{\Psi(k,\lambda)}^{ii\,j}(f_{\Psi(k,\lambda)}^{ii\,j}(t)), \tag{6}$$

which shows that the value of jj th function of i th enterprise depends on the values of j th function of ii th enterprise in times $\{t_{k-\lambda}, t_{k-\lambda+1}, t_{k-1}\}$;

$$f_k^{ij}(t) = G_{\Psi(k,\lambda)}^{\Lambda(i)\,j}(f_{\Psi(k,\lambda)}^{\Lambda(i)\,j}(t)), \tag{7}$$

where the function G indicates the existence of values of j th function for i th enterprise depending on the values of j th function of enterprises from the set at the time points $\{t_{k-\lambda}, t_{k-\lambda+1}, t_{k-1}\}$;

$$f_k^{ij}(t) = G_{k-1}^{ii\,jj}(f_{k-1}^{ii\,jj}(t)), \tag{8}$$

which shows the relationship between j th function of i th enterprise and jj th function of ii th enterprise on the previous time period;

$$f_k^{ij}(t) = G_{k-1}^{\Lambda(i)\,\Theta(j)}(f_{k-1}^{\Lambda(i)\,\Theta(j)}(t)), \tag{9}$$

which indicates on a relationship between the values of j th functions of i th enterprise and of the functions from the set $\Theta(j)$ of enterprises group $\Lambda(i)$ in the previous step;

$$f_k^{ij}(t) = G_{\Psi(k,\lambda)}^{\Lambda(i)\Theta(j)}(f_{\Psi(k,\lambda)}^{\Lambda(i)\,\Theta(j)}(t)), \tag{10}$$

which shows that the value of j th function of i th enterprise on k th time interval depends on the values of functions from the set $\Theta(j)$ of enterprises group $\Lambda(i)$ at previous time intervals $\{t_{k-\lambda}, t_{k-\lambda+1}, t_{k-1}\}$;

Assume that all models that determine the behavior of the agent are formed. Structural and parametric identification model is based on a database (DB) for the actual point in time, the bank mathematical models (BMo) and a set of identification methods (BMe). Thus, the agent in formation stages served as a set

A = <DB, BMo, BMe> (11)

Method of agent forming will have the following steps:

Step 1. Establish the range of internal and external features of the system (In, Out).

Step 2. Let $|In| = n$, $|Out| = m$.

Step 3. For $i = 1$ to n do (to internal features):

Step 3.1. For all the data with capacity $|DB|$ to do:

Step 3.1.1. For $k = 1$ to $|BMo|$ do:

Step 3.1.1.1. For $l = 1$ to $|BMe|$ do:

Step 3.1.1.2. Implement structural and parametric identification of i th internal feature of system based on data from DB using k th model and l th method, if possible.

Step 3.1.1.3. End of cycle.

Step 3.1.2. End of cycle

Step 3.2. End of cycle.

Step 4. Among all the obtained models by certain criteria to choose the best and consider it one of the programs under which the agent operates.

Step 5. Perform steps 3-4 items for external features.

As a result of the above method for the entire sector enterprises will be provided a set of agents (multiagent system), which will have a specific architecture and program operation. Note that the architecture of the agents has minor differences, but the program will vary much more.

In the next stage of multiagent technology will offer a method for operation of multiagent systems:

Step 1. Initialize the multiagent system using the above method, $i = 0, t = t_0$.

Step 2. To monitor the environment that incident to sector enterprises

Step 3. If in the environment held at least one change, then $i = i + 1$, $t = t_i$, and to record to DB.

Step 4. If changes not occurred but ended the period of monitoring, to record the values of features enterprise characteristics to DB

Step 5. If any of the values of internal features of one of the systems has changed, due to a change in the spectrum of problems, management strategy or structure of production that do not affect the changes in the environment, then record the appropriate entries to DB, $i = i + 1, \quad t = t_i$.

Step 6. Perform structural and parametric identification of the model based on the obtained data.

Step 7. If obtained information and models usage suggest the possibility of critical modes, to warn the decision maker.

Thus, the results of the methods for forming and using agents allow the information support of the decision maker. In practice, there is uncertainty, which is caused by the variety by different purposes of the different decision makers, no significant amount of data about the results of the enterprise activity. These problems can be partially overcome by insider information or analysis of simulation results under certain assumptions, integrating features of enterprises-competitors and implementation assumptions about the interaction with them as unconscious opponent (nature).

Idealized object of study and believing that one is in the interest of the enterprise, you can get the conclusions that will be the basis for decision making processes for relevant decision maker. It is necessary to carry out continuous analysis and monitoring of the production market. Knowing the extent and dynamics of demand, as well as the dynamics of its features, you can make informed decisions about further development. These solutions are solutions of the synthesis problem. Dual to it is the problem of the analysis, which in this case is to determine the consequences of decisions based on the results that are predicted on the basis of models.

Fragmented model of sector market

Analyzing the effective functioning of a particular enterprise and across the industry, it is necessary to consider a set of features. Assuming that enterprise performance is determined by their values, we assume that

$$S_j =< X_j^1, X_j^2, ..., X_j^{d1} >, \tag{12}$$

where S_j - is an j th enterprise, $(X^1, X^2, ..., X^d)$ - the features of the enterprise, and

$$S_j^t = (x_j^{1t}, x_j^{2t}, x_j^{dt}), \tag{13}$$

where t - time, moreover $\exists k \in [1; +\infty): t \in [t_{k-1}, t_k]$, $x_j^{it} - X^i$ feature value of j th enterprise at the time t .

Formulae (12) and (13) give the possibility of constructing a fragmented sector model, a two-dimensional version of which is shown in Figure 3. Generally, such a model can be written as

$$F_M =< X_1^1, X_1^2, ..., X_1^d, X_2^1, X_2^2, ..., X_2^d, ..., X_M^1, X_M^2, ..., X_M^d > \tag{14}$$

Thus, the fragmented model is multidimensional (M+1) rectangular hyper parallelepiped illustrating the trajectory of the enterprise activity in the space of its internal and external features. The length of one side of the hyper parallelepiped increases, since it corresponds to the time. Each cell of the model corresponds to a period of time, which did not change the values features of the enterprise. If at least for one company they have changed, then $t_k \rightarrow t_{k+1}$ and in the model there is another band that reflects the new time interval. In addition, due to a variety of enterprises and the values of their features, we claim that no two trajectories of functioning enterprises pass through some cell. Note that there are restrictions, i.e. $\forall X_j \in [X_{j\min}, X_{j\max}]$. If the value of at least one features beyond the established limits, then holds an exclusive option functioning. The relevant enterprise is excluded from consideration and requires individual solutions.

Fragmented model is the basis for the preliminary analysis of the overall state on the market. Its practical application associated with the use of technology OLAP (online analytical processing), performance cuts of model, bringing it to a smaller dimension. These operations allow determining the range of features that are informing and influencing on the overall efficiency of the activity. The decision maker’s solutions would affect not only the optimization of the enterprise activity, but also adjusting model parameters and process control planning in the company.

	3	3							4						
		3				2	2	2	4						
		3				2		4	4		1	1			
		3	3	3	3	2		4	1	1	1				
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Figure 3. A fragmented model of sector

Conclusions and perspectives

The functioning of natural systems based on the principles of self-organization. Most of them can be used to optimize the activity and artificial systems, including industrial enterprises. Proposed in this paper multiagent technology corresponds both a natural mechanism and functioning elements of the industry. The need to adhere to market principles of the economy makes it necessary decisions for each enterprise according to the performance of businesses and other environmental conditions. The suggested technology allows to the decision maker for the benefit of one company to act in accordance with the market situation: to develop production, eliminate it, improve the competitiveness of products and so on.

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Bibliography

[Gurevich, 2005] Л.А. Гуревич, А.Н. Вахитов. Мультиагентные системы // Computer Science. – 2005. – С. 116-139.

[Ivashchenko, 2011] А.В. Иващенко. Мультиагентные технологии для управления производством в реальном времени. Режим доступа: www.smartsolutions-123.ru.

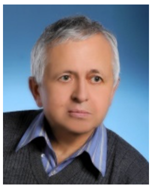
[Nasloboev, 2011] А.В. Маслобоев, В.В. Быстров, А.В. Горохов. Мультиагентная информационная технология поддержки управления качеством высшего образования // Вестник МГТУ. – 2011. – Том 14, № 4. – С. 854-859.

[Skobelev, 2003] П.О. Скобелев. Открытые мультиагентные системы для оперативной обработки информации в процесах принятия решений : Дисс. …докт. техн. наук. – Самара, 2013. – 418.

[Snytyuk, 2010] В.Е. Снитюк, Б.В. Мысник. Адаптация концепции «искусственной жизни» к моделированию процессов функционирования производственных предприятий//Журнал передовых технологий. – 2010. – № 4/4(46). – С. 4-8.

[Voloshyn, 2013] А.Ф. Волошин, М.В Коробова, Т.В. Колянова. Математическая економика – Киев, 2013. – 224с.

Authors' Information



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