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A. E. GOLOSKOKOV, T. A. DRACH, S. E. SHAPOVAL

FUZZY IDENTIFICATION OF THE STATE OF IT CORPORATION

Проаналізовано методи та підходи до вирішення задачі управління корпорацією. Розглянуто економічні, соціально-психологічні, адміністративні методи управління корпорацією. Розглянуто ситуаційний, системний, ситуаційний нечіткий підходи до управління корпорацією. Винесено рішення застосовувати ситуаційний нечіткий підхід до вирішення задачі дослідження. Запропоновано використовувати алгоритм кластеризації k -середніх для того, щоб розподілити нечіткі ситуації по класам. Вирішено задачу кластеризації. Вирішено задачу ідентифікації стану ІТ-корпорації.

Ключові слова: управління корпорацією, нечіткі ситуації, ситуаційне нечітке управління, ідентифікація стану корпорації.

Проанализированы методы и подходы к решению задачи управления корпорацией. Рассмотрены экономические, социально-психологические, административные методы управления корпорацией. Рассмотрены ситуационный, системный, ситуационный нечеткий подходы к управлению корпорацией. Принято решение применять ситуационный нечеткий подход к решению задачи исследования. Предложено использовать алгоритм кластеризации k -средних для того, чтобы распределить нечеткие ситуации по классам. Решена задача кластеризации. Решена задача идентификации состояния ИТ корпорации.

Ключевые слова: управления корпорацией, нечеткие ситуации, ситуационное нечеткое управление, идентификация состояния корпорации.

The methods and approaches to solving the problem of corporate governance are analyzed. Economic, social-psychological, administrative methods of corporate management are considered. Situational, systemic, situational fuzzy approaches to corporate management are considered. It was decided to apply a situational fuzzy approach to solving the research problem. It is proposed to use the k -means clustering algorithm in order to distribute fuzzy situations by classes. Clustering problem is solved. The task of identifying the state of IT corporation. An example has been calculated with which you can conduct a comprehensive study of the state of the object, which allows you to get a full understanding of the estimated IT corporation not only at the time of the assessment, but also in the retrospective and forecast periods.

Keywords: corporate governance, fuzzy situations, situational fuzzy management, identification of the state of the corporation.

Introduction. Currently, the evolution of the community is largely dependent on IT technology. The IT industry is one of the four priority sectors for Ukraine's export strategy. In recent years, there has been an increase in the number of IT corporations in Ukraine, which are rapidly expanding. The creation of an effective IT-technology requires the creation of an optimal IT-corporation management system. Thus, the task of managing the IT corporation becomes urgent.

The modern concept of "management" means the process of coordination of various activities taking into account their goals, conditions of implementation, stages of implementation.

Considering the management process as an element of the organization, it is necessary to determine what tasks the management of a specific organization performs as it does, that is, to understand which sectors are the subject of coordination and regulation and in what way this coordination is carried out.

The Corporation has the following characteristic features: nonstationarity of the process occurring in the system, a large amount of information, the impossibility of constructing a mathematical model from the standpoint of the classical control theory. The solution of the management task stipulates the following tasks: aggregation of information, identification of the state of the system and solution of the management task.

The present work is devoted to aggregating information and solving the task of identifying the state of IT-corporations. It is proposed to use the elements of situational control and the mathematical apparatus of the theory of fuzzy sets.

Since a large amount of information complicates the construction of the situational management model, it is proposed to aggregate it using cluster analysis.

Analysis of the research problem. The quality of IT-corporation management is largely determined by the effectiveness of decisions taken by leaders of different levels - the higher, middle and lower levels. To make such decisions, managers need to have reliable, timely and regular information about the state of affairs [1].

Particularly acute problems of reliability, timeliness and regularity of management information face large IT corporations. Information systems are the only way to collect, process and present data in a form that is convenient for making managerial decisions.

It can be concluded that in modern conditions IT-corporations need a tool that allows using the available resources as efficiently and economically as possible. The use of foreign experience, concepts and technologies can be of great use only if it is really a progressive experience and if it is used taking into account the specific conditions in which a particular IT corporation is located. Management systems (methodologies, approaches, computer programs) should be flexible enough so that they can be adapted as needed, with various changes in the "external environment".

Thus, it is timely to introduce into the IT-corporation a management system that could make its work more efficient and, as a result, lead to an increase in profits.

Description of the research object. In the work as an object of research is considered an IT corporation, which represents the domestic software industry in the world market.

At the head of the IT corporation is the General Director. He represents it in all institutions and state organizations, concludes contracts, issues orders for the corporation, opens accounts in banks and performs many other functions.

Directly subordinate to the director of the IT corporation are three deputies: marketing, economics and personnel, as well as the chief accountant and legal counselor.

IT-corporation has a linear-functional (combined) management structure, because it is based on a close combination of linear and functional connections in the management apparatus. It provides such a division of labor, in which the linear links make decisions and manage, and the functional – consult, inform, coordinate and plan economic activities. The basis of the organization of functional actions is based on a linear principle. This is illustrated by Figure 1.

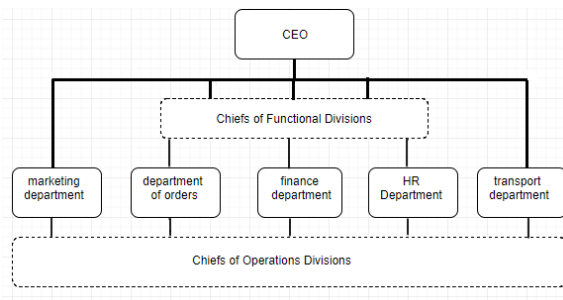


Figure 1 – Linear-functional control structure

The linear-functional structure is also characterized by weak horizontal connections between functional divisions. Therefore, quite often some similar control functions are not coordinated enough. The constant need to harmonize decisions at the level due to the variety of horizontal links causes a significant slowdown in the timing of the implementation of the goals, a decrease in the quality of decisions made, an increase in management costs.

It should be noted that the main criteria for the effectiveness of the IT corporation can be its indicators: the profit that the corporation receives for one quarter (hryvnia), the number of timely completed orders (pcs per quarter), costs, per order (man-hours).

All indicators of IT-corporation activity tend to grow, and the growth rate of profit from sales of products and services exceeds the growth rate of sales proceeds, which in turn exceeds the growth rates of prime cost by a favorable trend.

To solve the management problem, it is proposed to use an unclear situational approach. Since the IT corporation has an established, mature production: a large-scale, mass. The goals here are clear and rarely change. The main thing is to be able to exit in the best way from the unfavorable situations that are created, to avoid failures in the production process.

The management decision always consists in the choice of certain quantities, which are called "management". They, in turn, determine the values of other quantities - the phase coordinates.

To solve the research problem, the following phase coordinates:

- x_1 – number of departments in the IT company (pcs);
- x_2 – number of technologies for creating software products (pcs);

x_{3i} – number of employees who own a certain technology (person), $i = \overline{1, n}$;

x_{4l} – amount of funds allocated for a particular project (computers), $l = \overline{1, n}$;

x_{5m} – number of reserve frames (people), $m = \overline{1, n}$.

Thus, the vector of phase coordinates describing the state of the control object has the following form:

$$X = \{x_1, x_2, x_{3i}, x_{4l}, x_{5m}\}.$$

Due to the large amount of information, it is necessary to aggregate it using fuzzy logic [2]. Each attribute is formalized by a linguistic variable. Next, we set the base set for the characteristic. So, every sign x_i ($i \in J = \{1, 2, K, p\}$) is described by the corresponding linguistic variable $\langle x_i, T_i, D_i \rangle$, where $T_i = \{T'_1, T'_2, K, T'_m\}$ – term-set of a linguistic variable x_i (or a set of linguistic values of the trait; m – number of characteristic values); D_i – basic feature set x_i .

To formalize fuzzy situations of the IT-corporation management process, the vector of phase coordinates:

x_1 – number of departments in IT-corporations.
 \langle "Number of departments in IT-corporations", $T_1, D_1 \rangle$;

$T_1 = \{\text{"few", "enough", "much"}\}; D_1 = \{5; 20\}$.

x_2 – number of technologies for creating software products.
 \langle "Number of technologies for creating software products.", $T_2, D_2 \rangle$;

$T_2 = \{\text{"few", "enough", "much"}\}; D_2 = \{10; 30\}$.

x_{3i} – number of employees who own a certain technology, where, $i = \overline{1, n}$.
 \langle "Number of employees who own a certain technology", $T_3, D_3 \rangle$;

$T_3 = \{\text{"few", "enough", "much"}\}; D_3 = \{15; 50\}$.

x_{4l} – number of reserve personnel who own a certain technology, where i is the project, $l = \overline{1, n}$.
 \langle "Number of reserve personnel who own a certain technology", $T_4, D_4 \rangle$;

$T_4 = \{\text{"few", "enough", "much"}\}; D_4 = \{10; 20\}$.

x_{5m} – amount of funds allocated for a particular project, $m = \overline{1, n}$.
 \langle "Amount of funds allocated for a particular project", $T_5, D_5 \rangle$;

$T_5 = \{\text{"few", "enough", "much"}\}; D_5 = \{30\ 000; 100\ 000\}$.

Next, we form the control vector. For the considered domain, it has the form:

u_1 – number of employees in IT-corporations (IT-specialists);
 \langle "Number of employees in IT-corporations", $T_1, D_1 \rangle$;

$T_1 = \{\text{"few"}, \text{"enough"}, \text{"much"}\}; D_1 = \{100; 1000\}.$

u_2 – volume of investments (in UAH);

<"Volume of investments", T_2, D_2 >;

$T_2 = \{\text{"few"}, \text{"enough"}, \text{"much"}\}; D_2 = \{100000; 300000\}.$

u_3 – technical support (computers);

<"Technical support", T_3, D_3 >;

$T_3 = \{\text{"few"}, \text{"enough"}, \text{"much"}\}; D_3 = \{100; 1000\}.$

u_4 – number of orders of IT solutions (pcs per quarter);

<"Number of orders of IT solutions", T_4, D_4 >;

$T_4 = \{\text{"few"}, \text{"enough"}, \text{"much"}\}; D_4 = \{10; 100\}.$

The criteria for assessing the functioning of the corporation are as follows:

K_1 – profit that the corporation receives for one quarter (in UAH);

<"Profit that the corporation receives for one quarter", T_1, D_1 >;

$T_1 = \{\text{"few"}, \text{"enough"}, \text{"much"}\}; D_1 = \{20000; 100000\}.$

K_2 – number of timely executed orders (units per quarter);

<"Number of timely executed orders", T_2, D_2 >;

$T_2 = \{\text{"few"}, \text{"enough"}, \text{"much"}\}; D_2 = \{3; 15\}.$

K_{3i} – costs, for the performance of one order (man hours), $i = \overline{1, n}$;

<"Costs, for the performance of one order", T_3, D_3 >;

$T_3 = \{\text{"few"}, \text{"enough"}, \text{"much"}\}; D_3 = \{1000; 8000\}.$

The process of functioning of the system reflects the behavior of the system in time and can be represented as a successive change of its states. If the system changes one of its states to another state, then it is customary to say that the system goes from one state to another.

Statement of the research problem and the choice of the method of its solution. The paper considers the IT-corporation, which has a linear-functional management structure. In modern development this organization is one of the leaders in software development. IT-corporation has established, fulfilled and large-scale production. Effective activity of the corporation is satisfactory, however management believes that the IT corporation has a great potential for organization.

Thus, to solve the problem of managing an IT corporation, first of all, it is necessary to solve the problem of identifying the state of the corporation and to develop measures to ensure its further effective development.

So, the IT-corporation's need to redefine target targets and their implementation can be met by creating flexible tool-and-methodical support, including two main processes: information aggregation, IT-corporation status identification.

Thus, the first stage is reduced to the transformation of the detailed information into "packages" (aggregates) of data that allows to analyze the IT corporation in terms of a

small number of relevant aggregate variables that include profit, costs, orders (intermediate and final), the number of employees in the corporation, the amount of investment, the amount of technical support, etc., under conditions for which the initial data are known with varying degrees of detail.

The second stage is the identification of the state of the IT corporation. It consists in determining from the input and output values of such a situation from a particular class of situations, in which the real system under investigation is equivalent. In accordance with this, it is necessary to define a class of situations models, among which the most suitable (current) model of the situation will be chosen. That is, it is necessary to conduct a comprehensive study of the state of the object, which allows to get a full understanding of the estimated IT corporation not only at the time of the assessment, but also in the retrospective and forecast periods [2].

The management of the corporation should be able to implement its proposed management in any period (once a week, once a month, once a quarter). Then compare the results that were before the introduction and the results were obtained after the innovations. Thus, the IT corporation for 2 years should reach an entirely new level of management, which would lead the corporation to achieve its main goal.

Economic, social-psychological, administrative methods of corporate management are considered. Situational, systemic, situational fuzzy approaches to the management of the IT corporation.

It is revealed that the application of the above methods, as well as the situational approach, is ineffective for our research task. So there are many signs that are quite difficult to describe the situation in the IT corporation. All this is a complex mathematical model. The authors decided to switch to fuzziness. Namely, it was decided to apply a situational fuzzy approach to solving the research problem.

The task of clustering. There are data on the situation describing the state of the corporation. In cluster analysis this is called observation. Each situation is described by signs, for example, the number of technologies for creating software products, the number of funds allocated for a particular project, the number of reserve personnel, the number of employees who own certain technology and the number of departments in the corporation. They form a vector representing the situation. This vector has the form of a list of numbers that can be interpreted as coordinates of a multidimensional space [3].

In order to distinguish classes of situations using the fuzzy k -mean method, we use the MatLab application package for numerical analysis.

In the Statistics Toolbox section, there is a standard function `kmeans()`, access to which allows to obtain clustering results for the sample. The input data for it are sampling (value k), as well as numerous parameters and settings.

Authors were given the following data for the calculation of the test case: $k=3$, k – a set of characteristics that adequately reflect the properties of the research object (Table 1).

Table 1 – Initial data for the clustering process

An object	The parameters that characterize IT corporation				
	x_1	x_2	x_{3i}	x_{4l}	x_{5m}
IT corporation	{5; 20}	{10; 30}	{15; 50}	{10; 20}	{30000; 100000}

The data given in table 1 form 3 classes ("few", "enough", "much") to describe each of the pranks characterizing the corporation. These vectors are represented in the form of a list of numbers in Table 2. Next they will be interpreted as coordinates of the multidimensional space for the MatLab.

The set of situations formed by the authors is partially given in Table 2.

Table 2 – Developed situations

Situation	Values
S_0	{ few; few }
S_1	{ few; enough }
...	
S_8	{ much; enough }
S_9	{ much; much }

The initial data are heterogeneous, and their estimates by parameters are not consistent, which corresponds to the real situation.

We determine the value of the proximity measure for each criterion. Let us write the obtained values for characteristic x_1 in Table 3.

Table 3 – Normalization of the heterogeneity of values

Normalized values										
0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
few			enough				much			

We calculate the distance between the centers of the parameter clusters. The results are shown in Table 4.

Table 4 – The distance between the centers of the clusters

Distance between signs	The value obtained
x_{1k} and x_{2k}	0,234521
x_{2k} and x_{3ik}	0,158114
x_{3ik} and x_{4lk}	0,424264
x_{4lk} and x_{5mk}	0,455522
x_{1k} and x_{5mk}	0,357071
x_{1k} and x_{3ik}	0,331662
x_{1k} and x_{4lk}	0,223607
x_{2k} and x_{4lk}	0,308221
x_{2k} and x_{5mk}	0,150000
x_{3ik} and x_{5mk}	0,165831

As you can see, the smallest value between the second (the number of technologies for creating software products) and the fifth (the amount of funds allocated to a particular project). And the greatest between the third and

fourth signs, as well as between the fourth and fifth.

Next, a pair of numbers is formed, which consists of the value of the characteristic and the value of the membership function. Then we get the formed situations.

Let's test the test case. Let the current situation S_0 will be formulated as follows: IT-corporation has 4 technologies used to write IT solutions and 3 employees with a certain technology, that is, the total number of developers is 12 people. Also now, the IT corporation is developing a low-budget project (40 000 hryvnia).

The initial data are heterogeneous, and their estimates by parameters are not consistent, which corresponds to the real situation.

We determine the value of the proximity measure for each criterion and write the results in Table 3.

Next, a pair of numbers is formed, which consists of the value of the characteristic and the value of the membership function. Then we get the formed situations.

Let's test the test case. Let the current situation S_0 will be formulated as follows: IT-corporation has 4 technologies used to write IT solutions and 4 employees with a certain technology, that is, the total number of developers is 12 people. Also now, the IT corporation is developing a low-budget project (40 000 thousand hryvnia).

Let's write the current situation S_0 cas follows: there is a small number of technologies for creating software products, a large number of employees who possess certain technology and a small amount of funds allocated for a particular project. Situation S_0 characterized by signs x_2 – number of technologies for creating software products, x_{3i} – the number of employees who possess certain technology, x_{4l} – amount of funds allocated for a particular project. Thus, we determine that the characteristic x_2 belongs to the class of situations {few}, x_{3i} belongs to the class of situations {much}, x_{4l} belongs to the class of situations {few}.

We have the situation S_0 is formed as follows:

$$S_0 = \{<0,25/"few">, <0,9/"enough">, <0,35/"few">\}.$$

Further it is necessary to identify the current situation.

The main advantage of the algorithm is its simplicity. Simplicity usually means high execution speed and efficiency compared to other algorithms, especially when working with large data sets [3].

The two main disadvantages of the method in the medium are invested in the sensitivity to explosions and the initial choice of centers of gravity.

The task of identification. To identify the state of the IT corporation, it is necessary to consider the situation in which it is at the moment. It is necessary to compare the input fuzzy situation S_0 with every fuzzy situation $S = \{S_1, K, S_n\}$. As a measure to determine the degree of proximity of the fuzzy situation of a fuzzy situation S_0 the degree of fuzzy inclusion of a fuzzy situation will be used S_0 in an unclear situation S_i . Enabling the fuzzy

situation S_0 in an unclear situation S_i . The definition of the degree of inclusion of situations, based on determining the degree of inclusion of fuzzy sets. Degree of inclusion of the situation S_i in the situation S_j is given by:

$$v(S_i, S_j) = \&v(\mu_{S_i}(y), \mu_{S_j}(y)).$$

Value $v(\mu_{S_i}(y), \mu_{S_j}(y))$ is the degree of inclusion of a fuzzy set $\mu_{S_i}(y)$ in a fuzzy set $\mu_{S_j}(y)$.

For a test render, let's use the example described above. The authors identified 22 reference situations. All reference situations are assigned to three levels of the hierarchy. Using the formula, we will determine the degree of inclusion of the current situation in each of the available. To do this, let us take the part formulated by the authors, earlier situations [4].

To the type of fuzzy situations S' include situations that characterize the state of performance of the functional responsibilities of the corporation.

Situations S' are determined by the following set of characteristics (factors):

- x_2 – number of technologies for creating software products (pcs);
- x_{3i} – number of employees who have a certain technology (person);
- x_{4i} – amount of funds allocated for a particular project (computers).

Situations S'' are determined by the following set of characteristics (factors):

- x_1 – number of departments in the IT corporation (pcs);
- x_{5m} – number of reserve frames (people).

Situations S'_i includes fuzzy situations that characterize the quality of management in a corporation, and also depend on the profit of an IT corporation for one quarter. Fuzzy situations S'_i three characteristics, namely: x_2, x_{3i}, x_{4i} .

Situations S'_2 characterizes the degree of personnel training in new technologies. Fuzzy situations S'_2 two characteristics, namely: x_2, x_{3i} .

Situations $S'_1 = \{S'_{11}, S'_{12}, S'_{13}\}$, $S'_2 = \{S'_{21}, S'_{22}\}$ we will present in Table 4.

Table 4 – Part generated by the authors, situations

Situation	Values			The signs
S'_1	0,25 / few	0,45 / enough	0,9 / much	x_2
	0,20 / few	0,60 / enough	0,9 / much	x_{3i}
	0,10 / few	0,20 / enough	0,8 / much	x_{4i}
S'_2	0,25 / few	0,45 / enough	0,9 / much	x_2
	0,25 / few	0,45 / enough	0,9 / much	x_{3i}

So, the situation S'_{11} characterizes the small profit of the IT corporation for the quarter. Situation S'_{12} characterizes the sufficient profit of the IT corporation for

the quarter. Situation S'_{13} characterizes the big profit of the IT corporation for the quarter. Situation S'_{21} reflects an insignificant degree of training in new technologies. Situation S'_{22} reflects a significant degree of learning new technologies.

For the test miscalculation, a stack of situations is necessary that belong to the situation S' , because it is characterized by signs x_2, x_{3i}, x_{4i} .

It was determined that the test situation S_0 belongs to the class of situations S' , because situations S' are determined by the following set of characteristics (factors): x_2, x_{3i}, x_{4i} .

Further, it is necessary to determine the degree of inclusion S_0 in each of the situations S'_i . As S'_2 characterized by all but two signs x_2, x_{3i} , then it does not suit us.

Determine the degree of inclusion of the current situation S_0 in the situation S'_{11} :

$$v(S_0, S'_{11}) = (0,25 \rightarrow 0,25) \& (0,9 \rightarrow 0,2) \& (0,35 \rightarrow 0,1).$$

Determine the degree of inclusion of the current situation S_0 in the situation S'_{12} :

$$v(S_0, S'_{12}) = (0,25 \rightarrow 0,45) \& (0,9 \rightarrow 0,6) \& (0,1 \rightarrow 0,2).$$

Determine the degree of inclusion of the current situation S_0 in the situation S'_{13} :

$$v(S_0, S'_{13}) = (0,25 \rightarrow 0,9) \& (0,9 \rightarrow 0,9) \& (0,1 \rightarrow 0,8).$$

We come to the conclusion that the situation S_0 is closest to the reference fuzzy situation S'_{12} , which indicates a large increase in the number of personnel in the corporation and a sufficient profit for the quarter.

Let us now calculate the degree of fuzzy equality of situations. The degree of equality of two fuzzy subsets \tilde{A}, \tilde{B} set of X is defined as:

$$\mu(\tilde{A}, \tilde{B}) = \&(\mu_A(x) \leftrightarrow \mu_B(x)).$$

If $\mu(\tilde{A}, \tilde{B}) \geq 0,5$, then the sets are fuzzy equally, if $\mu(\tilde{A}, \tilde{B}) \leq 0,5$, then the sets are mutually indifferent.

Based on the foregoing, it is necessary to determine the degree of fuzzy equality of the situation S_0 in each of the situations S'_i according to the formula 2.

Taking into account the above calculations, we determine the degree of fuzzy equality of the situation S_0 with the situation S'_{12} .

$$\begin{aligned} \mu(S_0, S'_{12}) &= (0,25 \leftrightarrow 0,45) \& (0,9 \leftrightarrow 0,6) \& (0,35 \leftrightarrow 0,2) = \\ &= 0,35 \& 0,8 \& 0,25 = 0,8. \end{aligned}$$

Hence we have that $\mu(S_0, S'_{12}) \geq 0,5$. And this means that the situation S_0 and the situation S'_{12} fuzzy equally.

So, based on the received calculations, namely, the

calculation of the degree of fuzzy inclusion and calculation of the degree of fuzzy equality of situations, it can be concluded that at the moment the corporation has a large increase in the number of personnel and sufficient profit for one quarter [5].

Thus, it is possible to identify the situation in the IT corporation, which can occur at any time and will be considered current. With the help of this identification, the management of the IT corporation at any time can receive reports on the state of affairs in the corporation, as well as obtain the necessary management decision to achieve its specific objectives.

Conclusions. It has been established that the most effective approach to the management of an IT corporation that has an established, established large-scale production is a situational fuzzy approach.

Since it is necessary to process a large amount of information, it is suggested to use the k-means clustering algorithm in order to distribute fuzzy situations.

Data aggregation is performed. Namely, information was converted into data aggregates, which allowed the IT corporation to be analyzed in terms of a small number of relevant aggregate variables.

The state of the IT corporation was identified. Namely, it is determined by the input and output values of such situations from a certain class of situations, in which the real system under investigation is equivalent. An example has been calculated with which you can conduct a comprehensive study of the state of the object, which allows you to get a full understanding of the estimated IT corporation not only at the time of the assessment, but also in the retrospective and forecast periods.

Then, using the results obtained, we propose the solution of the control problem.

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Відомості про авторів /Сведения об авторах /About the Authors

Голоскоков Олександр Євгенович – кандидат технічних наук, професор, Національний технічний університет «Харківський політехнічний інститут», професор кафедри програмної інженерії та інформаційних технологій управління; тел.:(066) 268-84-48; e-mail: goloskokov@ukr.net

Голоскоков Александр Евгеньевич – кандидат технических наук, профессор, Национальный технический университет «Харьковский политехнический институт», профессор кафедры программной инженерии и информационных технологий управления; тел.:(066) 268-84-48; e-mail: goloskokov@ukr.net

Goloskokov Oleksandr Evgenovich – Candidate of Technical Sciences(Ph. D.), Professor, National Technical University "Kharkiv Polytechnic Institute", Professor at the Department of PIIT; tel.: (066) 268-84-48; e-mail: goloskokov@ukr.net

Драч Тетяна Олександрівна – студентка, Національний технічний університет «Харківський політехнічний інститут», кафедра програмної інженерії та інформаційних технологій управління, м. Харків, Україна; тел.:(093) 902-68-41; e-mail:tatianadrach_if32b@ukr.net

Драч Татьяна Александровна – студентка, Национальный технический университет «Харьковский политехнический институт», кафедра программной инженерии и информационных технологий управления, г. Харьков, Украина; тел.: (093) 902-68-41; e-mail: tatianadrach_if32b@ ukr.net

Drach Tetjana Oleksandrivna – student, National Technical University "Kharkiv Polytechnic Institute", Department of Program Engineering and Information Technology Management, Kharkiv, Ukraine; tel.: (093) 902-68-41; e-mail: tatianadrach_if32b@ ukr.net

Шановал Сергій Євгенович – студент, Національний технічний університет «Харківський політехнічний інститут», кафедра програмної інженерії та інформаційних технологій управління, м. Харків, Україна; тел.: (093) 359-38-39; e-mail: serhiishapoval_if32g@ ukr.net

Шановал Сергей Евгеньевич – студент, Национальный технический университет «Харьковский политехнический институт», кафедра программной инженерии и информационных технологий управления, г. Харьков, Украина; тел.: (093) 359-38-39; e-mail: serhiishapoval_if32g@ ukr.net

Shapoval Serhii Evgenovich – student, National Technical University "Kharkiv Polytechnic Institute", Department of Program Engineering and Information Technology Management, Kharkiv, Ukraine; tel.: (093) 359-38-39; e-mail: serhiishapoval_if32g@ ukr.net

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