The use of Dyadic and Advisory Opinions in the Model of Group Dynamics of the Decision-Making Process for Software System Developers

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Abstract. In the article the system review and a number of original results which are not exhaustive in research of mathematical models of formation and functioning of members of teams of developers of program systems at generation of optimum decisions are spent. However, they reflect the general methodology of building and studying of applied mathematical models of dynamic functioning of firms (teams) - developers of program systems of optimization of solutions, and also can be effectively used in solving tasks of a wide class of management of social and economic systems. It should be noted that mathematical modelling has been used as the main research apparatus to develop mechanisms of innovation development management of the firm (teams) and its personnel while making optimization decisions. On the one hand, the use of mathematical models makes it possible to obtain reasonable conclusions and establish quantitative relations between significant phenomena and processes. On the other hand, it should be remembered that in building any mathematical model, a number of assumptions are introduced and the results of the analysis of these models are only fair within their limits. Therefore, probably, it is not necessary to consider results of mathematical modelling as final result, and as a certain "algorithm", having substituted in which the numerical values corresponding to this or that real situation, it is possible to receive the exhaustive answer to a question how to operate innovative developments of teams of developers of systems and firms in which they exist using iterative meetings. Advantages of using mathematical modelling consists in that it allows to explain correctly observed phenomena and connections between them, to predict the future development of internal processes of mutual relations between members of a team of system developers, that is it gives the chance to choose optimum variants of decisions.

Keywords: software systems developers; model; group dynamics; decision-making process; information technologies.

1 Introduction

The article deals with the issues of forming professional opinions about interrelations between developers of software systems and conflicts permanently arising between them. Axelrod [1], a pioneer in the field of group dynamics of forming professional opinions, focuses the attention of the researchers of this question on two key factors of these processes which are necessary for cognitive modelling of the diffusion of social influence processes (the developers of program systems become more similar) and homophily (the developers of program systems prefer to interact with similar others). He was one of the first to focus on the fact that differentiation of different cultures in a team can arise as a result of imitation through dyadic object relations. The results of such object relations indicate that the interaction of software system developers through homophily and social influence on each other can contribute to sustainable collective states or contribute to the formation of effective solutions, professional explanation of which often exceeds the individual or micro level of individual members. Also in scientific research, [15] it has been determined that these collective states of individual objects can be determined by mathematical values such as averages and statistical distributions. Such research paradigm forms the modern vector of development direction when trying to determine the initial conditions under which social influence at the micro-dyadic level is transformed into macro-masses of diffusion through multiple iterations of mutual exchange [2]. In the process of research, several mathematical models have been developed that emitted the emergent properties of diffusion of exchange. Which, in turn, can be grouped into two groups: one is the models of exchange of discrete opinions, where these opinions, or other ontological equivalents, can take discrete values; the other is the formation of continuous models of exchange of opinions, where they are represented by real numerical values.

In the context of formation of continuous group dynamics of exchange of opinions, which was introduced by Defiante et al. [6], and other authors have applied it to network effects, trust and many other social phenomena. Thus, it is possible to assert that individuals of a team of developers of program systems first meet in a running pair, and then in the consequence of iterations of rapprochement converge to a common denominator of opinion, in that cases when their corresponding individual opinions are close to each other. Using a peculiar mechanism of limited confidence, which is based on biased confirmation. [25] After a certain time of transient evolution and social group dynamics such process leads to achievement of the final state, at which either full consensus of opinions is reached or a group of developers of program systems is divided into a certain number of clusters, when all individuals in one formed cluster share one common opinion.

These representations of social interactions of software systems developers in the group dynamics of individual views do not take into account daily communication attitudes that characterize successful IT companies, such as meetings, discussion platforms (brainstorms) and other channels of receiving mass information, in which individual team members exchange different points of view and can collectively, while effectively influence each other in the formation of a management decision. In essence,

the aggregation of individual opinions of team members, which are embodied in collective effective decisions, such as voting, is formed by factors that are related to the structure and size of information channels of communication and decision-making. When a team of developers takes part in a collective discussion, which arguments are put forward to convince opponents, how the discussion is organized in time, as well as criteria for the acceptability of voiced proposals, can lead to a transformation of initial preferences. For example, in the author argues that discussion clusters people in the direction of their initial knowledge because of objective social pressure and limited knowledge within a discussion group.

At the same time, having conducted several empirical studies of discussion processes, some authors make another conclusion that effective discussion can work as a stabilizing or deterrent effect on changes in opinion.

The authors [14] express the opinion that organization of a discussion can encourage moderate agreement of individual opinions of the members of program systems' developers' teams if it is of procedural nature. Or polarize individual opinions if they encourage team members to be selfish. All these objective phenomena of diversity of individual opinions can bring a certain degree of inconsistency into well-known stable states of opinions (clusters) which are formed in classical group dynamics of opinions and can be somehow preliminary modelled.

The distribution of individual opinions by members of the system development teams is also used to track the process of convergence of opinions into "effective" or adequate opinions in working groups. In the study [17], the authors consider how interactions between agents (team members) affect the diffusion of accurate information. [3] They focus their research on network effects rather than on protocols for correctly discussing individual opinions. In our context, generating the right solution corresponds to a solution that is derived from a dialectical situation in which all alternative arguments for and against should be considered. If there is an optimal criterion for the correctness of collective decision-making, which can be used to assess the effective results of developed consultative procedures and consensus decision-making. Thus, the process of discussion presupposes the existence of certain normative conditions for objective decision-making, the consensual collective decisions obtained on its basis.

The reflection process is a way to get as close as possible to the ideal state of opinion of the members of the system development teams, where the group expresses its suggestions as if it has all the necessary arguments at its disposal for making a decision. In the scientific work Barabbas considers empirical evidence of discussion, which significantly increases the necessary ones, which in turn correlates with the correct answers to the objective questions voiced. Until recently, models of diffusion of individual opinions did not take this objective dimension into account. At the same time, models that mix deliberative and dyadic interactions may well do so and take it into account.

Model development can shed light on the fact that consistency and accuracy in the opinions of a team of software systems developers can largely depend on how the process of making certain decisions is structured. The total number of debates and the number of subjects of individual opinions that can participate in them can slightly reduce the accuracy of judgment, while having little impact on the consistency of decision

making by the development team. Thus, we emphasize that the results in decision making depend on such factors, namely, how many effective arguments the agents have and how they advance in iterative discussion.

2 Consolidated model for collective decision-making with discussion

Let's consider the model of collective acceptance, the consolidated decisions between members of teams of the developers, consisting of three objects: members of teams of their arguments and summary tables for discussion. Members of teams it is the closed cluster of discussions their arguments represent parts of the accessible information, and in tables collective decisions which have been accepted at the organisation of all iterations of consultative interactions between members of teams of developers of program systems are consolidated and fixed.

Review of the proposed model. Here we propose to consider in detail the review of the model. For this purpose, we will present team members of software systems developers and a set of objects that make collective consolidated solutions possible in a multi-agent system.

Overview of members of development teams (agents) and objects in the proposed model. Arguments are statements of objects, which are connected with each other by a relationship in decision making. They are characterized by the criterion of support of some value or principles. Team members are characterised by their interest in discussing ideas when generating consolidated solutions, by the arguments they have at the moment, and by their knowledge of the arguments. Team members communicate with each other or collectively through meetings, making individual arguments in the public arena. The permanent communication of team members creates the conditions for possible updating of their initial opinions. The tables show the entities that contain information about both the agents and their arguments. All this information is consolidated and controlled by the management of the development team, which develops and fixes the general rules in the process of collective discussion and decision making. At the same time, they regulate the frequency of consultative interactions between team members, as well as the conditions of collective consolidated acceptability of the discussed information for decision-making. Availability of a body for making a consolidated decision, namely a person or an automated system that can reveal an adequate epistemological status of different sets of voiced arguments. [24]

Reflexive model of the uniform opinions of the members of the teams of software systems' developers. Let us analyse the reflexive model of forming the opinions of the members of the team of software system developers. For this purpose, let's consider a set $N = \{1, 2, \ldots, n\}$ of team members with their individual opinions. At the same time, the strategy of choosing the opinions of the *i*-members of the developer's team is the choice of actions $y_i \geq 0$ which requires the expenses of Cobb-Douglas $c_i(y_i, r_i) = r_i \varphi\left(\frac{y_i}{r_i}\right)$ where $r_i > 0$- the opinion of each type of a member determines the efficiency of its activity which can be represented as a $\varphi(\cdot)$ – monotonically convex function. [22] If to suppose that the aim of forming a consolidated solution of opinions on joint work

of the members of program systems' developer teams is the total realization of the set task with minimum development costs.

$$\sum_{i\in N} c_i(y_i, r_i) \to \min_{(y_1, y_2, \dots, y_n)} \quad (1)$$

$$\sum_{i\in N} y_i = R \quad (2)$$

In his or her ideas each member of the team of software systems' developers can predict what actions or viscose's other team members will choose, what individual and total expenses will be at that. If the choice of actions is performed many times and the choice of actions is observed by some team member who is different from his or her views, he or she will have to correct his or her views and at the next choice to use a "new" set of views. Let us consider two cases of information structures (conceptions r_y and r_{yk}) and five variants of subjective stories of the game, where we will consider that subjective stories and information structures of all members are the same, otherwise the number of possible variants of choice increases sharply, which simultaneously causes the appearance of ten new models (Table 1).

Table 1

The model of forming the homogeneous opinions of team members

Substantial history of fashion	Structure of in formativeness of team members	
	$\{r_{ij}\}$	$\{r_{iik}\}$
y_i	Models 1	Models 6
c_{-i}	Models 2	Models 7
c	Models 3	Models 8
$(y_{-i}; c_i)$	Models 4	Models 9
$(y_{-i}; c)$	Models 5	Models 10

Suppose that the *i*-th member of the team of software systems developers has an awareness structure observing $\{r_{ij}\}$, the actions of other members. In this case the information balance will have such a mathematical function:

$$y_i^*(\{r_{ij}\}) = \frac{r_{ij}}{\sum_{j\in N} r_{ij}}, \ \ i \in N \quad (3)$$

The rationalized representation of opinions of the members of the team of software systems developers will acquire the following mathematical representation:

$$\Omega_i^1 = \{r_{ij}\} > 0, j \in N\backslash\{i\} | r_{ij} / \sum_{j\in N} r_{ij} = x_j, \ \ i \in N\backslash\{i\}\} \quad (4)$$

Dynamics of representations of opinions of the i-th member of the team of software systems developers will acquire the following form:

$$y_{ij}^{t+1} = r_{ij}^t + \gamma_{ij}^t \left(w_{ij}^t(x_{-i}^t) - r_{ij}^t\right), \frac{r_{ij}}{\sum_{j\in N} r_{ij}}, \quad i \in N\backslash\{i\}, t = 1,2, \dots, i \in N, \quad (5)$$

where $w_{ij}^t(x_{-i}^t) - j$- projection of the nearest k (r_{ij}^t), $i \in N\backslash\{i\}$ is the point of set Ω_i^1.

A lot of stable information equilibriums are given on the graph, where the initial state of opinions is indicated by a dot, the rhombic is the true values of the developed consolidated solution, and the arrow indicates the change of opinions of team members Fig. 1.

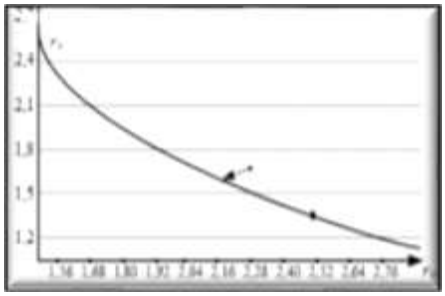

Fig. 1. – Distribution graph of multiple information equilibriums

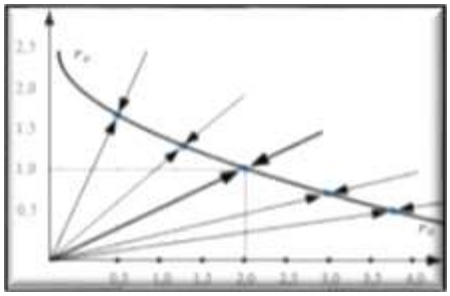

Fig. 2. – Graph of the nodes of consistency of stable information equilibriums

The stability equation at (*n = 2*)

$$r_{12}r_{21} = r_1 r_{2.} \tag{6}$$

In terms of content, the mathematical condition (6) means that a few first members of the software development team overestimate (underestimate) the other member of the team, in contrast to so many times the second underestimate (underestimate) the first. An aggregate characteristic of the team of software systems' developers in the whole case can be conventionally considered a product of all the team members. A lot of mutual ideas satisfy $(r_{12};\ r_{21})$ its mathematical condition (6) - it is a kind of hyperbola on the corresponding plane. An example case $(r_1 = 2;\ r_2 = 1)$ is given in Fig. 2.

The conducted mathematical analysis allows not only to define a set of equilibria according to condition (6), but also to investigate areas of their attraction: from condition (5), therefore, it follows that the dynamics of mutual representations corresponds to such equation:

$$\frac{\Delta r_{12}^t}{\Delta r_{21}^t} = \frac{\gamma_{12}^t}{\gamma_{21}^t}\ \frac{\gamma_{12}^{t-1}}{\gamma_{21}^{t-1}}, \mathrm{e} = 1,2,\dots,. \tag{7}$$

According to the mathematical condition of equation (7), at constant and identical "iterations" the trajectory of change of mutual representations of opinions of members of a team of software systems developers will be direct, passing through zero. The slope angles of these lines are shown in Fig. 2, Where the areas of attraction of the points of their intersection with the hyperbola condition (6), which is determined by the starting point (for example, any starting point selected in Fig. 2 by a thickened line $r_{12} = r_{21}/2$, so true balance is executed).

The scientific view on this mathematical representation is interesting from the point of view of information management by different opinions, according to the fact that we know its end point, the center can easily calculate many initial points, starting from which the members of the program systems developers' teams will find the necessary balance for the center (the optimal solution). Having finished considering the example,

we can conclude that stability of the developers' team and their coherence in making right decisions while performing the tasks can be achieved, in particular, for false ideas of team members about each other's opinions. Getting out of the false balance requires team members to get an additional quantum of information for each other's opinions. [2, 4-8]

So, the models of forming professional opinions for making decisions about the activity of homogeneous teams of developers of program systems, described by the terms of reflexive games, allow setting and solving the tasks of managing the process of forming highly qualified team decisions. [9-12]

Indeed, by considering the conditions of the models (1 - 7) it follows that the presence of the opinions of the team members and the history of the rallies for the consolidation of decision-making in the process of the game is essential. Therefore, one of the management possibilities is, firstly, to create different situations of production activity (providing identification of essential characteristics and opinions of team members) and, secondly, to provide maximum communications and access to all essential information. [13-15, 20-23]

Besides, a mathematical analysis has been carried out to show that the speed of formation of a consolidated opinion in a professionally balanced team (speed of convergence to balance) is significantly influenced by parameters and sizes of iterations, which appear in the procedures of dynamics of collective behavior of iteration meetings by members of the teams of software systems developers. [19] The influence on these parameters can also be considered as control on the part of central bodies on the process of program system development. [16-18, 23]

Thus, the considered "reflexive" models of formation and functioning of decision making in professional teams of program system developers reflect such properties as autonomy, consistency and stability of interaction of different team members.

Conclusions

In the article the system review and a number of original results which are not exhaustive in research of mathematical models of formation and functioning of members of teams of software systems developers are conducted. However, they reflect the general methodology of building and studying applied mathematical models of dynamic functioning of firms (teams) - developers of program systems, and also can be effectively used in solving tasks of a wide class of management of social and economic systems.

From the point of view of the theory of mathematical models' research it is necessary to admit that different results of studying the teams of program systems' developers, received in psychology and sociology, today are not fully reflected in formal models. For many models, there are certain difficulties in obtaining analytical solutions. Almost the "branch" specificity is not taken into account (for example, such widespread in practice class of formation and existence of teams taking into account psychotypes of each team member in sports teams is not yet a subject of deep system, formal, theoretical research.

A promising direction for further applied research, in our opinion, is the expansion of the class of formation using mathematical models of coexistence of psychotypes of members of real organizations and teams, for which formal models of management are formulated and used.

So, in this research we consider a complex of mechanisms of organizational management of innovative development of the firm (team) of software systems developers, in particular, mechanisms of financing, management of organizational projects, institutional management, staff motivation and personnel development management. Many classes of models are considered for the first time, the model of self-development, games with variable composition, multi-criteria model of stimulation. Their further development is a promising task for future research.

It should be noted that mathematical modelling has been used as the main apparatus of research for development of mechanisms for management of innovative development of the firm (teams) and its personnel. On the one hand, the use of mathematical models allows to obtain reasonable conclusions, to establish a quantitative relationship between significant phenomena and processes. On the other hand, it should be remembered that, building any mathematical model, a number of assumptions are introduced and the results of the analysis of these models are only fair within their limits.

Therefore, probably, it is not necessary to consider results of mathematical modelling as the final result, and as a certain "algorithm", having substituted in which the numerical values corresponding to this or that real situation, it is possible to receive the exhaustive answer to a question, how to operate innovative development of teams of developers of systems and firms in which they exist. The advantages of the use of mathematical modelling consists in the fact that it allows to correctly explain the observed phenomena and connections between them, to predict the future development of internal processes of relationships between the members of the team of systems developers, that is, it is optimal to choose the variants of development.

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