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Formalized Description of a Business Game Scenario Aimed at Assessment of the Qualifying Characteristics of Personnel

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Abstract: The study analyzes the game-theoretic model of a non-cooperative interaction between several agents. It is assumed that agents make decisions simultaneously and independently without being able to negotiate the selected action or redistribute the resulting usefulness (prize), etc. Researchers review the mathematical models and methods of formalized description of a business game scenario indicate the position and the role of business games in the process of evaluating the qualifications of personnel. In addition, researchers offer a Qualification Assessment Method.

Key words: Business game, agent, parallel processes, multi-role game, qualifications of the personnel, player

INTRODUCTION

Organizational and technological level of the modern industrial enterprises is largely determined by the creation and application of effective mechanisms for the formation and implementation of strategic development plans and the effectiveness of the operational management of all production, logistics, organizational and economical processes that aim to achieve high production profitability, development and improvement of production. In this regard, building the organizational structure of the enterprise management is a complex multi-layered problem. Principle sand methods of the organizational structure development are directly dependent on many factors. The most significant of these are the specifics of particular production, sets of technological processes used, production volumes, capacity utilization, tactical, technical and quality parameters of products, standardization and certification issues, qualification level of technical, administrative and management personnel, management system applied, organizational and legal form, regulatory and legal framework of the enterprise, organization of internal and external documents circulation (Barinov *et al*., 2011a-c).

Development the organizational structure in an industrial environment is a paramount task in relation to other tasks of the industrial process control. Formulation and solution of this task at a high scientific and technical level is a prerequisite for the effective organization of production, high competitiveness of products, growth of financial and economic indicators, continuous dynamic development and improvement of production (Pugachev, 2002; Platov, 1991; Ostroukh, 2011a, b; Krasnynskiy *et al*., 2012).

Relevance of the topic is determined by the need to optimize the organizational structure of enterprise management as a "top-level" task to be primarily settled as a basic component of an effective and successful functioning of any industrial enterprise regardless of the products purpose and production volumes.

Game-theoretic model of non-cooperative agents interaction: Each agent selects an action xi belonging to the admissible set X_i, $i \in N = \{1, 2,\ldots, n\}$, i.e., the set of agents (Platov, 1991; Gureev *et al*., 1999; Petrosyan *et al*., 1998; Novikov and Chkhartishvili, 2003; Gubko and Novikov, 2002). Agent may select an action once, simultaneously and independently. Agent i wins depending on his own action $x_i \in X_i$, the vector of actions:

$$x_{-i} = \left(x_1, x_2, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n\right) \in X_{-i} = \prod_{j \in N/\{i\}} x_j \quad (1)$$

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N{i} opponents and the state of nature $\theta \in \Omega$ and is described by a real-valued pay off function:

$$f_i = f_i(\theta, x), \text{ where}$$
$$x = (x_i, x_{-i}) = (x_1, x_2, ..., x_n) \in X' = \prod_{j \in N} X_j$$

is the vector of actions of all agents. At a fixed value of the state of nature, the totality Γ = (N, {X_i} i∈N, {$f_i(.)$} i∈N) of multiple agents, sets of their possible actions and objective functions represent the game in normal form. Game solution in this model (equilibrium) is the set of stable vectors of agents, in one sense or another.

It is assumed that each agent will strive to choose actions that are best for him in a given situation (in terms of the value of its objective function). His environment will be the totality of the state of nature $\theta \in \Omega$ and the game environment:

$$x_{-i} = (x_1, x_2, ..., x_{i-1}, x_{i+1}, ..., x_n) \in X_{-i} = \prod_{j \in N/\{i\}} X_j$$

The principle of choosing an action (at the fixed environment and state of nature) in this model is defined as follows:

$$BR_i(\theta, x_{-i}) = \arg\max_{x_i \in X_i} f_i(\theta, x_i, x_{-i}),\ i \in N \quad (2)$$

Graphs are an adequate mathematical tool for modeling relationships between objects. Within the framework of these models of network interaction, nodes of the graph are the players and the arc is interpreted as the presence of directional communication between the players.

Suppose there is a set of players N = {1, ..., n}, each of whom possesses some information. A player can report the information to other players (maybe not to all). Then, the message structure will be described by a finite graph whose vertices are the players and the arc ij only appears in the graph in case player i hands over some information to player j. If we denote the set of all graphs with the set of vertices N by Θ (N) then the interest of the player i in a given connections structure can be described as a pay off function f_i: Θ(N)→ℜ, i∈N which determines whether the player has managed to implement various structures.

Thus, the model of network game includes the set of players N = {1, ..., n} and the set of pay off functions f_i: Θ(N)→ℜ, i∈N.

Under the conditions of previous example, the prize which player i receives due to messaging player j, equals pij where as the costs of player j for sending a message to player i equal c_{ji}. A player who receives information from another player can transmit it further over the network. Researchers introduce the factor of information distortion $\alpha \in (0.1)$ for transmission via a single arc. Then, the prize f_i (g) of player i in the network g = <N, E>∈Θ(N) can be expressed as:

$$f_i(g) = \sum_{j \in N, j \neq i} p_{ij} \alpha^{\delta_g(j,i)} - \sum_{j:ij \in E, j \neq i} c_{ij} \quad (3)$$

where, δg (j, i) is the length of the shortest directed path from player j to player i in the graph g (if the path is missing, the following is true δg (j, i) = +∞).

It is believed that players can somehow affect the formation of certain network connections. However, their role in the formation of connections may be more complex than that shown in the examples where the formation of bond ij depends on player i's decision.

In many online games, bonding requires the consent of both players for example for some reason, a player may refuse to accept information from another player. Therefore, in order for network game model to become Strategic Model it is necessary to formalize the possibility of players to form bonds.

Player i's wish to form bond ij can be described as a variable x_{ijout}, which equals one, if player i wants to form bond ij; otherwise, it equals zero. Index "out" of a variable indicates that the connection ij to the player i is outgoing. If x_{ijout} equals one, researchers say that player i has a proposition to player j.

Similarly, researchers can define the variable x_{ijin} which means that player i accepts the formation of an arch ji from player j. Index in suggests that the arch ji is incoming to player i. If x_{ijin} equals one, researchers shall say that player i accepts player j's offer.

Action x_i of player i in a network game is a pair $x_i = (x_{iout}, x_{iin})$ of vectors $x_{iout} = (x_{i1out},..., x_{inout})$, $x_{iin} = (x_{1iin},..., x_{niin})$. Set of all pairs of such vectors is denoted by X_{i0}.

Thus, player's action determines the set of his opponents, to whom the player wants to build an outgoing connection and the set of opponents whose incoming communication he declines. This way, in each game, the set X_i of player i's possible actions is a subset of X_{i0}.

Profile of players' actions in a network game is a pair $x = (x_{out}, x_{in})$ of square matrices of size n, the elements of which are components of allowable x_{ijout}, x_{ijin} players' actions. Multiple profiles of actions in a network game is the cartesian product:

$$X = \prod_{i \in N} X_i$$

Environment x for player i is a pair $x_{-i} = (x_{-iout}, x_{-iin})$ of matrices of size n×(n-1) whose elements are the components of possible actions x_{ijout}, x_{ijin} of all players except player i. Profile of actions x consists of the player's actions xi and his environment x_{-i}; in this case, researchers assume that $x = (x_i, x_{-i})$.

Suppose that a certain profile of actions $x = (x_{out}, x_{in})$ is implemented. Then, if we assume that the formation of bond ij requires only the consent of both players, the resulting network g is determined by element-wise multiplication of the matrix x_{out} by the transposed matrix x_{in}, i.e., $g = x_{out} \otimes x_{in}$ T. The set of networks attainable at a given set of profile actions X is denoted by G (X).

As a result, the Strategic Model of a network game can be defined as a set $<N, f_i, X_i, i \in N>$ the set of players N, their pay off functions $f_i(\cdot)$, $i \in N$ and the sets of admissible actions $Xi \subseteq X_{i0}$, $i \in N$.

Formalized description of a business game: Along with other methods of learning, business game contributes to the accumulation of managerial experience, close to the real. With the help of business games this can be done a little better than with other methods of cognition (Barinov *et al.*, 2011a-c; Pugachev, 2002; Platov, 1991; Gureev *et al.*, 1999; Ostroukh and Nikolaev, 2013a, b; Vladimirovich *et al.*, 2014; Vladimirovich and Evgenievna, 2011; Ostroukh and Vladimorov, 2012; Ismoilov *et al.*, 2013). Firstly, the game closely mimics the existing reality; secondly it creates a Dynamic Organizational Model and thirdly it urges to address the goals more intensely.

These circumstances determine the relevance of using business games in the process of personnel training and evaluation of its qualifying characteristics.

To organize and conduct computer business games we need to do the following (Ostroukh, 2011a, b; Krasnynskiy *et al.*, 2012; Barinov *et al.*, 2012):

- Provide a game guide and a support team
- Prepare methodological and technical support
- Adapt the business game to the relevant participants and conditions
- Prepare future participants for the game and assess their level of readiness for the game
- Perform the necessary calculations to assess the consequences of different solutions, generate optimal or rational decisions for each section of the game

Case study method lies in the fact that learner faces a situation associated with some specific moment of system functioning. The task of trainees is taking collective management decisions in a particular situation. Typical features of case studies include:

- Availability of a real system model, the state of which is considered in a certain discrete point in time
- Collective decision-making
- Multi-alternative solutions
- Group has a common goal when making decisions
- System of group assessment of trainees' activities
- Ability to manage the emotional stress of trainees

Application of the case study method is advisable in cases when researchers consider a separate, relatively complex organizational, economic or managerial task, the only correct decision or the right decision of which is known in advance to the teacher. He/she has the final word when summarizing the results.

ROLE PLAYING

Such games are usually aimed at developing the ability to manage people. In order to carry out the game, researchers need to model management systems embedded in the structure of specific systems (Barinov *et al.*, 2011a, b; Pugachev, 2002; Platov, 1991; Gureev *et al.*, 1999; Ostroukh and Nikolaev, 2013a, b; Vladimirovich *et al.*, 2014, 2012a, b; Ostroukh and Vladimorov, 2012; Ismoilov *et al.*, 2013). When reviewing particular situations, the participants are assigned to roles that may be designed for a group. The goal of the game consists in the following: performers choose the optimal strategy of behavior at each stage of the game. In contrast to the analys is of specific situations in role games:

- A model of control system is required
- Decision taken by a trainee only affects the control system, rather than the object of control
- Complex model of the control system is dynamic in its nature; there is a role-based communication in which communication may depend on the flow of dialogue between the partners

Simulation games are games with a different target orientation to which some of these characterological features of role-playing games are not peculiar.

Such games may have only one role which is replicated (multiple copies created) by each participant who in turn, prepares his/her solution.

No models of the management system or the control object are available; only the model of environment in which the decision must be made. The activities of specific executives or professionals are simulated. Absence of conflict situation.

Organizational Activity Games (OAG): Organizational-activity games include problem role-playing, problem-oriented business games, approbation-search games and innovative games. OAG are used for solving complex social and industrial problems that require collaboration of specialists from different areas. The game is based on information about the state of the real system provided to players. Next comes the development, discussion and decision-making related to system management. Such games address the issues of management programs development, less often-operational management issues. The game reveals a complex of management challenges of socio-economic system and solutions to these problems. In OAG, researchers usually consider the states of system crisis, encouraging the increased motivation of participants and decisions that bring the system out of the crisis.

An approach in which there is a transition from games where participants choose their actions simultaneously (standard G_0 game) to hierarchical games in which a sequence of turns is fixed (first, the center makes a move and then-the participant) is of interest. We can further complicate the model by moving to games that are more complex. Let us carry out the logic of the transition from easier tasks to more complex ones (Fig. 1) in order for a more complex problem to be decomposed into simpler tasks.

If there is one subject that makes decisions (Fig. 1a) it is described in terms of the hypothesis of rational behavior as eager to maximize its objective function. Then, researchers can complicate the model and consider several subjects at the same level (Fig. 1b), describing their interaction with game G_0 in normal form. If we introduce a hierarchy for two subjects (Fig. 1c), their interaction is described by the game G_i where $i \in \{1, 2, 3\}$.

Let us assume that there is a structure "one leader-several subordinates" (Fig. 1d). Interaction of participants of the same level can be described by game G_0. "Superior-subordinate" interaction is described by game G_i. Such structure can be represented by the game G_i, determined on the game G_0, symbolically denoting it by $G_i(G_0)$. Now let us suppose there are a few leaders (centers) and several subordinates (Fig. 1d). On the lower level, participants play game G_0. In relation to them, the centers play a hierarchical game G_i but on their own level, the centers, in turn, play G_0. As a result, there is the following game: $G_0(G_i(G_0))$. Researchers can take a more complex structure with more complex interaction (Fig. 1e). This will be a hierarchical game between the levels, and at the same time, a "regular" game on each of the levels: $G_0(G_i(...G_i(G_0)...)$.

The basic idea is to decompose the complex structure of the game into a set of simpler structures and to use the research results of the latter. In addition, there is a deep

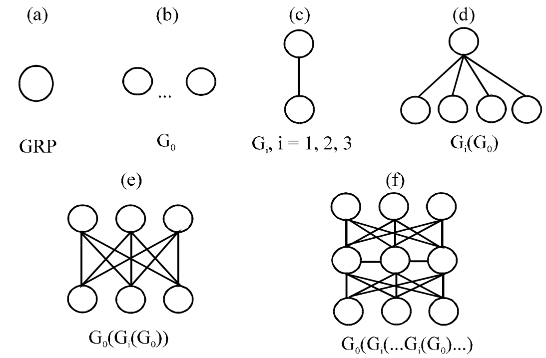

Fig. 1: Structure of business games

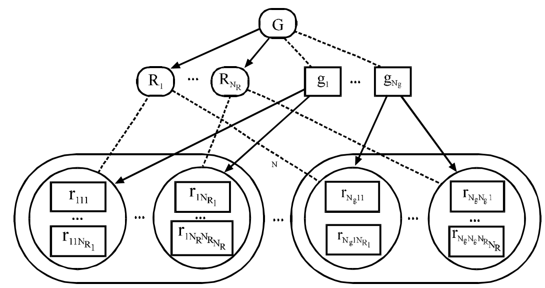

Fig. 2: General case of organizational and structural medium of a multirole business game

connection between games and structures-the time during which a subject makes a decision determines his/her "place" in the organizational hierarchy.

Undoubtedly it is useful to have such mechanisms of forming scenarios where multiple games are naturally combined to solve larger problems, including production situation modeling.

It is proposed to use multilevel approach to the description of scenarios which is now supported by "SOTA" Software. General case of organizational and structural medium of the multirole business game is presented in Fig. 2, in which:

- G: multirole Business Game (MRBG)
- R_j: roles provided in the game G $1 \le j \le N_R$ where N_R is number of roles in game G
- g_i: copies of game G; $1 \le i \le N_g$ where, N_g number of copies of game G
- r_{ijk}: roles in the copies of game G; $1 \le k \le N_{R_j}$ where N_{R_j} number of roles R_j

According to its structure, the individual single-copy BG that allows creating multiple interacting copies of its sole role is similar to the individual BG with a single copy of this role but with the difference that it supports multiple interacting copies of the game.

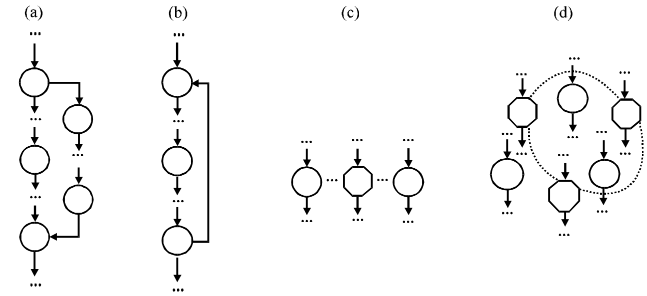

Fig. 3: Options for organizing the flows management; a) branching; b) cycle; c) synchronization of all copies within a single role and d) synchronization of all copies of all roles within the synchronizing contour

The dotted lines show the “class-copy” relationship. The arrows show affiliation. During the development of the BG body, scenarios provide for various options for organizing the management flows (Fig. 3). Octagons indicate synchronizing fragments.

The dotted line shows a contour of synchronization that combines fragments belonging to different roles (threads of the script). Only the copies of those threads which are part of the contour will be synchronized. Fragments of the figure respectively determine:

- Branching
- Cycle
- Synchronization of all copies within a single role
- Synchronization of all copies of all roles within the synchronizing contour

Functioning of BG framework is determined by the following parameters; the values specified during game development: number of BG copies: single or multi-copy, restrictions on the choice of roles.

FORMALIZING THE SCENARIO OF USER ACTIVITIES IN THE COURSE OF BUSINESS GAME FOR ITS FURTHER SOFTWARE IMPLEMENTATION

For efficient software implementation of user actions within a single business game, researchers propose to organize parallel processing within a single copy of the game (Ostroukh and Nikolaev, 2013a, b).

To support interacting parallel processes, researchers introduce additional fragments of 3 types, playing a supporting role (Fig. 4):

- Creating (C): fragments that create the background process
- Destroying (D): fragments that forcibly terminate the background process (Fig. 4a)
- Waiting (WE): fragments that block the execution of the main thread of the script awaiting the onset of an event associated with the implementation of a background thread. Their particular case (WT)-Waiting for the independent completion of the background process

The maximum waiting time can be set for the waiting fragment. In this case, it will block the execution of the main thread until the specified event related to the fulfillment of a background process takes place or before the expiration of the maximum waiting time (Fig. 4b). Occurrence of an event is associated with a change in the state of some resource whether it is the background process or any other object.

These additional fragments are also nonvisual (i.e., they do not have a visual representation). Background processes exist no longer than playing time of a structural element in the context of which they were generated. During the creation of a background process, its identifier is placed in the internal list of background processes of the player copy by which it was spawned. Player copy uses this list to forcibly eliminate background processes that should no longer exist (for whatever reason, corresponding fragments of the structural element did not terminate them).

P_k and P_m are background processes. Dashed arrows with solid tips show control activities related to the creation and destruction of background processes. Dashed arrows tipped with a corner show the messages from the background processes that signal the occurrence of an expected event. Bold arrows show interaction between the fragments of the main thread of the script and background processes as well as interaction between the background processes.

Fragments of the main thread of the script can interact with the background processes by means of COM-interfaces, shared memory, named pipes, files, databases and other shared objects. There is a combined version of background process completion (Fig. 4c), in

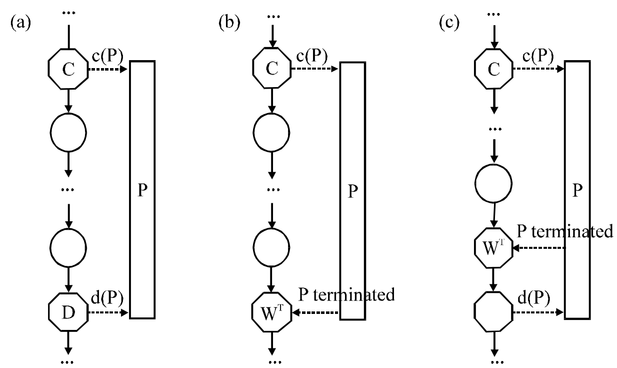

Fig. 4: Organization of parallel user processes; a) with forced elimination of background process; b) waiting until background process is completed and c) combined version of completion

which a background process is expected to self-complete for a given period of time. If the process has not been completed it is forcibly terminated.

Non-visual processes that perform subsidiary and servicing functions for the main thread of the script may be organized as background processes. User interface elements that can interact with the background process are implemented in the main thread the script. The use of parallel processing within a single player copy promotes the formation of a more compact script and its more efficient runtime (in terms of organization).

IDENTIFYING THE LEVEL OF STAFF TRAINING IN THE COURSE OF BUSINESS GAMES

To identify the level of training in the course of business games, researchers propose an iterative procedure (Barinov *et al.*, 2011a-c, 2012; Krasnynskiy *et al.*, 2012; Vladimirovich *et al.*, 2013a, b). Definition of the qualification level of a certain employee is a separate task and its solution can be reduced to processing of expert estimates provided by all other employees.

Suppose there are N participants of the business game during which either manually or automatically (analysis of actions in accordance with the script), each participant gives his assessment of the "skill level" to another participant; this information is entered into a matrix X, where x_{ij} is an estimate of participant j's "qualification" submitted by participant i. The consistency of those estimates is an interesting question. In full consultation, all lines must match.

However, in general, lines do not match due to the subjective opinions of each player. The most natural way of obtaining the resulting estimates is a weighted score of all participants:

$$X_i = \alpha 1\, x1_i + \alpha 2.\, x2_i +,...,+ \alpha N.xN_i \quad (4)$$

where, α_i is a true assessment of the participant. However, we shall deem the true assessment the one obtained after the transformation, considering all the previous ratings. The result is an iterative procedure:

$$X^{(k)} = \sum_{i=1}^{N} x_{ij}.X_i^{(k-1)} \quad (5)$$

Researchers assume that weights X(0) are the initial weights, defined by some participant, randomly or purposely selected. Next, researchers shall weigh the assessment of each participant using these weights and obtain new weights of each participant, etc.

CONCLUSION

This study considers the game-theoretic model of a non-cooperative network interaction between participants of a multirole business game. Researchers analyze and classify various business computer games in the retraining system of industrial enterprises. We also provide the expediency of the use of organizational-activity and multirole games. We propose a layered approach to describing the scripts of multirole business games, based on decomposition of games with a complex structure into games with a simple structure and constructing the corresponding hierarchy.

This study offers mechanisms for synchronization of user actions during multirole business games and the technique of assessment and reassessment of personnel qualification on the results of the business game which has allowed the development of software components that extend the functionality of software and tool design environment of the multirole business games.

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