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Chapter

About Operational Game Scenario Modeling

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Abstract

An original generalizing class of game-theoretic models (operational games or KOSH games) is presented, using which many micro-and macro - economic interactions are naturally modeled. Basic concepts of the theory of operational games and classification of such games, equations of dynamics of operational game interactions, and procedures for modeling scenarios of such interactions are described. Examples of operational games and some practical results of using this theory are given. The possibilities of fundamental and applied development of the considered direction of game-theoretic research are analyzed. The importance of this research is due to the fact that the original idea of the founders of game theory, which is to create an adequate accurate language for describing economic processes, has not been implemented to this day. In this paper, an attempt is made to implement this by accurately defining the concept of "operation" using static games of a well-defined type and considering dynamic ensembles of such static games.

Keywords: game theory, operations research, microeconomics, macroeconomics, scenario modeling, information and analytical system, digital platform

1. Introduction

In the fundamental work [1], a super-task was set to build an adequate accurate language for a complete and interrelated description of economic (in the broad sense) processes. This work is associated with the emergence of mathematical game theory. At the same time, its authors (J. von Neumann and O. Morgenstern) were very skeptical about the use of differential equations to describe economic processes (considering, that this mathematics adequately describes physical processes is not suitable for Economics, that some other mathematics is necessary here) and called for starting with building a description of the simplest facts of economic life that meets the standards of scientific rigor. Game theory, which began with the consideration of antagonistic (zero-sum) matrix games, which are a natural formalization of the well-known salon games, has now branched out into a number of powerful directions and confidently claims to become a generalizing standard in the accurate description of economic (social) processes [2–6]. At the same time, the description of any game always contains a finite set of players, a set of choices, and the principle of optimality for each player.

Games are divided into static (in which players make their choice once, at a designated point in discrete time, but before choosing, they can think, count, and exchange information) and dynamic (with multiple consecutive choices, possibly in continuous time). Dynamic games can be repetitive (played in discrete time, past draws do not affect the current one), multi-step (also in discrete time, but past draws affect the current one), differential (a controlled differential dynamic system is considered, in which control is divided between players with different goals). There is also a class of cooperative games that have a large number of players with simple behavior.

You can name thousands of scientific papers in the field of game theory. Many of them are informative and interesting. Which of these works to rely on is up to each researcher. This research is based on the fundamental works [2–6] of one of the leading schools of game theory, the school of Yu.B. Hermeyer and N. N. Moiseev, which are relevant to this work. In [2], games with non-opposite interests are proposed for consideration, analyzed, and developed. This class of static and multistep games differs from antagonistic games (zero-sum games) in part, that mutually beneficial cooperation, coalition interaction, and agreements are possible between players. As a basic principle of optimality that formalizes the interests and behavior of players, the principle of guaranteed results is considered, in which players expect the worst from other players and nature and, based on this, maximize their winnings. But other principles of optimality are also considered. A class of static hierarchical Hermeyer games is defined, which differ among themselves in the scheme of information interaction between the center player and players at the lower level of the hierarchy.

In [3], a class of games with a hierarchical vector of interests is proposed, which considers a set of zero-level players (individuals) who are United in coalitions that are first-level players. Players of the first level, in turn, unite in coalitions that are second-level players. And so on. The interests of each zero-level player are described as a convolution (linear, minimal, or otherwise) of their winning function as a zero-level player, multiplied by the so-called altruism coefficients of the winning functions of those first-level players (coalitions) that they belong to, and so on. The zero-level player determines the importance of the interests of all players of other levels, in which he participates directly or through a chain of coalitions, by his system of altruism coefficients. For a particular type of games in which each zero-level player distributes the resources available to him (the resource vector) among coalitions, Nash equilibria are constructively defined for convolution in the form of a minimum. Further, in the works of N. S. Kukushkin, strong equilibria were determined for both minimum convolution and linear convolution.

In [4], the original coalition principle of optimality (compromise with a metagoal) is proposed and considered, in which, along with their own interests (goals), players have a common interest – a metagoal. A Pareto set is constructed for a multi-criteria problem, in which the criteria are the players 'own interests, and then the maximum point for the metagoal is determined on this set.

In [5, 6], various issues related to multi-step games are investigated, and the applied possibilities of using the considered game models are analyzed.

A generalizing field closely related to game theory is the theory of operations research [7–10]. Due to the importance of this area in the context of this work, the main points of formation of the basic concepts of operations research will be discussed in the Section 2 devoted to this issue.

The term "operation" is very General and universal. Arithmetic or algebraic operation. Surgery. Military operation. Economic operation. Financial operation. Political or geopolitical operation. We can draw a natural conclusion that there is something in common in all this. But what is it, exactly?

Until the beginning of the 20th century, rather complex operations were studied only at a qualitative, descriptive level. Only mathematical and algebraic operations were studied at the level of strict definitions (at the level of established requirements for the concept of strictness).

Yu. B. Hermeyer proposed a very General qualitative definition of an operation as "a set of purposeful actions" [7]. It was assumed that operations are performed by intelligent and goal-setting entities (players, agents) alone or together, and that each of them wants to move towards achieving a particular goal when performing each operation. The goal can be formulated as a single-criteria (one specific indicator is maximized) or multi-criteria (the desire to increase several indicators) principle of optimality of the player (agent). Unfortunately, Yu.B. Hermeyer failed to increase the level of strictness of the definition of an operation by presenting mathematical definitions of the concepts "action" and "a set of".

In [7], a methodology for operations research is also proposed, in which the decision-maker (the operating side (OS), the first player, the LPR) and the operations researcher who helps the OS make decisions are distinguished.

When you carefully consider the definition of operation proposed by Yu. B. Hermeyer, it becomes clear that it contains everything that is designated by the word "operation". Indeed, the surgeon and assistants perform a set of purposeful actions, wanting to achieve a very specific result. Conducting a military operation is a set of purposeful actions to complete the task. The salesman wants to do his job by performing actions to move and deliver packages to recipients, minimizing his own costs. And so on.

The theories of non-antagonistic games and hierarchical games of Hermeyer [2], and the theory of games with a hierarchical vector of interests of Vatel-Hermeyer [3] are also associated with the name of Yu.b. Hermeyer. We can say that game theory and operations research theory merged for him, as well as for his friend and colleague N. N. Moiseev, into one whole, which requires the development of a single universal mathematical basis. This is quite consistent with the aspirations and attitudes of the founders of game theory [1]. But how do you find such a unified mathematical basis? Students and followers of Y. B. Hermeyer and N. N. Moiseev worked in the direction of its search.

Significant progress has been made in the study of issues related to uncertainty, aggregation, related constraints, and awareness in hierarchical games, and a decision support methodology based on the idea of "compromise with metacel" has been developed [4–6]. Based largely on the models of V. V. Leontiev to identify production functions and utility functions of the agents under consideration, the differential-difference direction of modeling macroeconomic processes was developed [11].

The theory of active systems was born in IPC RAS (V. N. Burkov) and actively developed in the theoretical and applied directions [12]. the idea of this theory is to generalize the theory of automatic regulation (TAR) in order to accurately describe socio-economic processes by assuming that some elements of TAR systems can be active, act expediently, and have expressions of will. In the works of one of V. N. Burkov's students D. A. Novikov and his colleagues, an attempt is made to organically synthesize the theory of active systems and mathematical game theory.

Analytical research of rather complex game-theoretic models, at the current level of "quickness of mind " of researchers, is very difficult. In this regard, it is very relevant to simulate the processes of interaction of many people.

The most advanced school of simulation modeling (not only in Russia) can be called the school of one of the students of N. N. Moiseev Yu.N. Pavlovsky [13]. This school was successfully conducted simulation SDI (it has been shown that the implementation of the so-called strategic defense initiative is impossible due to the fact that to control the entire surface of the planet would take more than a hundred thousand satellites), the Peloponnesian wars, geopolitical interaction between the three political-military alliances (the West, the Soviet Union with the allies, all the rest). A number of simulation models were built and successfully used by The F. I.

Ereshko school. A fruitful attempt to generalize the simulation methodology is presented in [14].

These achievements determined the possibility of generalizing the concept of accurate descriptions of social processes, the unifying formalism of game theory, the idea of the operation as the " a set of purposeful actions," the developments of simulation and of the theory of active systems, other achievements of the human mind in the exact modeling of complex, large-scale systems. As a candidate for such generalization, representatives of the Hermeyer-Moiseev school (in the process of solving of practical problems of scenario forecasting and decision support in industrial corporations, complexes, and industries) formed the theory of operational games and the related methodology of operational game scenario modeling [15–24].

Structurally, the work is structured as follows:

Section 2 analyzes the history of the formation of closely related game theory and operations research theory. The Central points of formation of basic representations of these theories are marked. The novelty of the proposed approach, which naturally grows out of these basic concepts, is indicated.

Section 3 presents the proposed precise definitions of the concepts "action", "operation", and other definitions necessary to describe operational games. The equations of dynamics of operational game processes are written out and analyzed. The classification of operating games and the principles of their use for solving applied problems are considered.

Section 4 uses simple examples to illustrate the methodology for constructing various scenarios for operational game interaction.

Section 5 outlines the prospects for fundamental and applied research of this class of game models.

2. Formation of the theory of operations research

The emergence of operations research as a field of precise research is rightly associated with the names of Mikhail Pavlovich Osipov and Frederick William Lanchester (1868–1946), who were the first to analyze military operations using differential Equations [8]. Almost simultaneously (M. P. Osipov was ahead of F. W. Lanchester after publishing their work "The Influence of the number of fighting parties on their losses" in the magazine "Military collection" in 1915), they proposed to consider and use the differential equation of Osipov-Lanchester, describing a military operation with a confrontation between two opponents. The status of each of the opponents in each moment of the confrontation was described by a number of troops and destructive power of weapons defined by the product quality on the number of weapons. Further, the study of operations using mathematical relations in the form of equations (including difference and differential equations) and restrictions (not only in the form of inequalities) has been widely extended to other areas of human activity.

In the second half of the 20th century, the scientific term "operations research" becomes generally accepted. This is due to the work of Russell Lincoln Ackoff (1919–2009), published in the 1960s [9]. R. L. Ackoff defines operations research as "the application of the scientific method by complex research teams to solve problems related to the management of organized (human-machine) systems in order to obtain solutions that best meet the goals of the entire organization." This definition can be considered a preliminary qualitative (descriptive) definition on the way to formalizing the social Sciences, which, of course, was based on other founders of the theory of operations research, including Yuri Borisovich Hermeyer (1918–1975) and Elena Sergeevna Wentzel, who worked in the same defense research organization. Hermeyer, a researcher and mathematician from God, a child who survived clinical death during a famine in the Volga region, winner of the first mathematical Olympiad in the USSR, was responsible for the development of torpedo control systems. Having started working at the invitation of his classmate in Moscow state University, N. N. Moiseev, at the legendary Computing center of the USSR Academy of Sciences (later named after its founder A. A. Dorodnitsyn), Yuri Borisovich creatively rethought and generalized the existing achievements of game theory and operations research [2, 3, 7]. Operation was defined by him as "a set of purposeful actions". In game theory, he became the founder of the theories of hierarchical Hermeyer games and games with a hierarchical vector of interests of Vatel-Hermeyer. The works of one of his closest associates, E. S. Wentzel, are also widely known [10].

To date, the definition of an operation Y. B. Germeyer can be called conventional. But it also needs to be clarified, since it lacks precise mathematical definitions of the concept of "action" and the operation of combining actions in the aggregate. The strictness of the definition of purposefulness by Hermeyer and his followers generally meets the "standards of scientific rigor". Purposefulness is linked to the concept of the "optimality principle", which is generally understood as several functions of variables describing the state of the game process (at the current moment or, in General, throughout the game process up to the current moment), maximized by a purposefully acting player (agent). The concepts of a decision maker (DM) and an operations researcher (OR) conducting research in the interests of the DM are introduced. In the case of a multi-criteria optimality principle, the OR task is to construct a Pareto set, and the DM task is to choose from this set. The followers of Yu. B. Hermeyer and N. N. Moiseev thoroughly investigated the issues of information exchange in hierarchical game interactions of a non-antagonistic nature, the issues of studying games with uncertainties and associated restrictions, the issues of bluffing and aggregation of information, the issues of finding equilibria and using the principle of guaranteed results in such games.

Other areas of work in game theory and operations research are also interesting. But it is hardly possible to do anything useful without going past what the founders did. It is possible that someone will offer a completely different view of the formalization of the Sciences of social interactions. But this, so far, is not visible.

The novelty of what is proposed by the author and his colleagues [15–24] can be represented as follows:

To date, we have considered multi-step games in which all players at each step (during each clock cycle of discrete time) play one common static game. When considering real game interactions, it is impossible to formulate or analyze such a game that adequately describes what is happening in reality. In this connection, we propose to assume that at each step, many (ensemble) static games are played that formalize real operations. If we talk about Economics, this corresponds to the wishes of the founders of game theory [1] to build accurate descriptions of "the simplest facts of economic life" that correspond to the "norms of scientific rigor". The game as a whole can be called a dynamic ensemble of static games (in the next step, the same static games are played again in new conditions).

Due to the fact that there are a lot of static games (operations) being played at any moment, they may conflict with each other (requesting the same resources, which are not enough for all requests, for example). This introduces the concept of a "regulatory rule", which in one way or another adjusts the operation requests so that there is no conflict.

In reality, actions not only implement certain technologies, but also improve them. In this regard, actions are divided into simple and operator actions.

Operator actions change parameters and functions that describe available actions and operations.

All this will be discussed later.

3. A basic concept of the operational games theory

Mathematically precise definition of the concept of "operation" is not known to this day (at least, for the author). To suggest such a definition is very relevant, since it would be the key to formalizing both Economics and many other qualitative social Sciences. In this case, it is necessary to take as a basis one or another qualitative definition of the concept of operation. Which one is the researcher's choice. Next will be made based on the definition of Y. B. Germeyer [7].

Let us make the definition of an operation proposed by Yu.b. Hermeyer ("a set of purposeful actions") more strict, starting with the question of what we will understand by "action". At the level of "subtle matters", even a magic spell can be considered as an action. May be one day this understanding will become normal. But this is a matter for the future. In the present time, it is reasonable to limit ourselves to the consideration of processes in which motion is observed in a particular finite-dimensional space, and the values of a finite number of numerical variables change (in discrete or continuous time). Then it is natural to consider any movement in a given space as an action (of players or/and natural factors). At the same time, formalizing real processes, it is natural to assume that each action (possibly representable as a set of simpler actions) is performed by a well-defined finite number of persons (players, agents), including nature. These players can participate in the Commission of an action either independently of each other, or by agreeing on something, having developed a common decision. In General, by agreeing on something. Any agreement is reached within the framework of a certain procedure of game interaction. The result of any agreement is a solution that can be formally represented as a vector of non-necessarily numeric variables. This vector will determine how exactly (on what scale, on which of the possible options) this action will be performed. From these considerations, a more precise definition of the operation appears below, in which the set of participants is called the set of LPR, the procedure for reaching an agreement is called the convolution function, and the decision made by the participants is called the vector of operation controls. However, in addition to moving actions in the finite-dimensional space of game interaction, we also consider operator actions that change the attributes of the description of operations (parameters of the convolution function and other functions describing the operation).

Strictly formally stated above, in the case of discrete time consideration of game interaction) is described as follows:

Let there be *N* players (one of which can be nature) interacting on a discrete time interval, whose phase state is denoted by the vectors $x_i, i = 1, \ldots, N$ $x_i \in G_{x_i} \subseteq R^{n_i}$. The dimensions of the vectors $n_1, \ldots, n_N$. We assume that their interaction is realized by performing simultaneous operations, during which the position of the game process changes in its phase space (which is the Cartesian product of the players 'phase spaces $G = G_{x_1} \times \ldots \times G_{x_N}$ $G \subseteq R^{n_1 + \ldots + n_N}$) and parameters of the operations themselves. When describing the operation, we will set

- a subset of the set of players $I_j \in \{1,, \ldots,, N\}$ (the set of LPR operations) that take part in making decisions on its implementation, in determining the vectors u_j of controls of the *j*-th operation during its implementation;

- function (vector-function) of convolution of the operation $f_j\left(\gamma_k^j\left(k \in I_j\right), \xi_j\right)$, which is an algorithm for determining the control vector of the operation by selecting players from the set of LPR operations γ_k^j (from their sets of choices for this operation H_k^j) and by realizations of uncertainties associated with this operation $\xi_j \in \Xi_j$;

- sets of simple PR_j and operator PR_j^o actions of this operation that are implemented during the operation and change the position of the game process in the phase space (simple actions) and the parameters of the operations themselves (operator actions).

The set of operations of the operating game is denoted by $OP = \{op_1, \ldots, op_M\}$.

We will consider the sets of simple and operator actions PR and PR^o to be uniform (common) for all operations. These sets belong to the sets of operations actions. The numbers of actions in the sets PR and PR^o are denoted by Q and Q^o, the numbers of actions of the j-th operation are Q_j and Q_j^o. We will also assume that the control vector of operations is unified for a given dimension L, which is common for all operations (some of its components may not be used in each specific operation). Each l-th simple or operator action of the j-th operation is generally associated with several sum functions of this action, depending on the control vector: $S_{jl1}, \ldots, S_{jl\alpha_{jl}}$ for a simple action or $S_{jl1}^o, \ldots, S_{jl\beta_{jl}}^o$ for the operator. These amounts (positive, negative, zero) are changed by the implementation of the action associated with this sum, the coordinate of the phase space G or the associated parameter of the action or operation.

At each moment of time of game interaction, the choices made by the players and the implementation of uncertainties determine some of the following operations: movement in the space $R^{n_1 + \ldots + n_N}$ But this move may take the process out of the allowed G area. In this regard, in each operating game, a regulatory rule must be defined that corrects the management of operations so that this does not happen. In the simplest and most common case of resource constraints, these rules can be proportional cuts to the resources requested by operations, operation priority systems, and others. We assume that such a rule is defined and the control vectors defined by the operation convolution functions become arguments of the transaction sum functions after correction by the control rule. The corrected control vectors will be marked with a wave ($\tilde{u}_j$).

Each sum S_{jlm} of a simple action of an operation is associated with a certain coordinate of the game interaction space $R^{n_1 + \ldots + n_N}$ x_{ir} $i \in \{1, \ldots,, N\}, r \in \{1, \ldots, n_i\}$, which this sum changes. Let us denote the δ_{jlm}^{ir} indicator equal to one if S_{jlm} is associated with x_{ir}, and zero otherwise. Then the system of equations for the dynamics of phase variables in the operational game interaction in discrete time is written as.

$$x_{ir}(t+1) = x_{ir}(t) + \sum_{j=1}^{M} \sum_{l=1}^{Q_j} \sum_{m=1}^{\alpha_{jl}} \delta_{jlm}^{ir} \cdot S_{jlm}\left(\tilde{u}_j(t)\right) \; i = 1, \ldots, N;$$

$$r = 1, \ldots, n_i \tag{1}$$

Similarly, (1) is written and the system of equations of dynamics of those parameters of actions and operations that can change the operator actions. If there are K such parameters and they are ordered, we denote them $\pi_1,\ldots,\pi_K$. The system of equations of their dynamics is written as

$$\pi_q(t+1) = \pi_q(t) + \sum_{j=1}^{M}\sum_{l=1}^{Q_j}\sum_{m=1}^{\beta_{jl}}\delta_{jlm}^{oq}\cdot S_{jlm}^{o}\left(\tilde{u}_j(t)\right)\ q = 1,\ldots,K; \tag{2}$$

Systems (1–2) together with the regulatory rule allow you to play (simulate) any operational game interaction of this operating game, if you know the players ‘choices and the implementation of uncertainties at each moment of the discrete time interval of this interaction. Players ‘choices are determined by their principles of optimality and their adopted behavior strategies (in the form of a program or synthesis), which can be very different. Uncertainties may or may not be described by certain probability distributions.

A very flexible language for describing legal and other restrictions, player obligations, assumptions about the behavior of other players, and the implementation of uncertainties is records of the form

$$\text{IF}\langle\text{condition}\rangle\text{THAT}\langle\text{action}\rangle\text{OTHERWISE}\langle\text{sanction}\rangle, \tag{3}$$

in which < condition> has the format of a logical sentence, the terms of which can be any simple statements about the values (or intervals of values) of phase variables, player elections, implementations of uncertainties, the presence and fulfillment of certain obligations, the players ‘awareness from the beginning of the game to the current moment; <action> and < sanction> have an imperative format for regulating (possibly interval) player elections at the current time.

To define the information structure of an operational game, you need to determine which subset of the complete information about the course of the game interaction each player has at each moment of this interaction. Full information is understood as accurate knowledge of the dynamics of phase variables, choices, implementations of uncertainties, sets of obligations, restrictions, and selected strategies for player behavior.

The dynamics of players ‘States is described as the dynamics of turnover and balance (or only balance) of their base accounts (variables of the space for developing game interaction) that arise as a result of various operations performed by players (production, investment, credit, purchase and sale of products and services, R & d, innovation and modernization, and others). The dynamics of arbitrarily complex indicators is represented as the dynamics of turnover and balance of analytical accounts, which are generally any computable functions of turnover and balance of basic and other analytical accounts.

Operations are described by the corresponding sets of LPR (players involved in making decisions about how, with which controls, these operations will be performed); sets of actions (transactions on basic accounts), the amounts of which are certain functions of the operation controls; convolution functions that determine the operation controls depending on the choices of players involved in the operation, and the implementation of uncertain factors.

Systems (1)–(2) have quite clear content meaning. In any operational interaction, there are many potentially possible operations that can be performed by participants. For each such operation, the technology of its implementation is known, including

- the number of possible participants, possibly different with a limit on the maximum number of participants;

- a list of actions that are performed during the operation, each of which can be implemented in different ways, with different implementation parameters;

- procedure for participants to agree on parameters for implementing actions.

At any given moment, some operations are performed, some are not. Some actions may be modernization in nature and change the technology of operations themselves.

In order to determine what happened at the current moment in discrete time, you need to go through the entire set of possible operations, for each of which you find out whether it was performed or not at the moment and determine how exactly it was performed, if so. During each operation, there is a swing (as the participants wanted to do it) and a blow (as it really happened), which is why the control vectors with the wave appear (the regulatory rule corrects the swing). The system (1) calculates the final movement in the interaction space, and the system (2) calculates the final change in the operation technologies themselves.

In the case of a surgical operation, actions are known practiced movements of the scalpel and other tools, in economic operations, economic facts related to production, purchase and sale, lending, investment, taxation, modernization, R & d, training, consumption, health care, etc. If we consider only production, exchange (purchase and sale of products, services, labor), investment, credit, tax and consumer transactions, writing out the system (1) will naturally lead to the well-known and used equations of the material and financial balance.

The universal nature of systems (1)–(2) opens up very interesting prospects. In particular, it is possible to raise and solve the issue of creating a software environment (platform) for generating in the menu regime a wide range of program systems for supporting micro - and macroeconomic decision-making.

In [16], we consider not only operational games with continuous accounts (variables) and discrete time, which are referred to as RD-games. Equations of dynamics of operational game processes can also be written for cases of continuous accounts and continuous time (RC-games), discrete accounts and discrete time (ZD-games), discrete accounts and continuous time (ZC-games). Differential games can be represented as RC games. The chess, checkers, and other finite games played by moves can be represented as ZD games. In the form of ZC games-game processes in continuous time, in which only a finite space of possible States of game interaction is essential.

4. Methodology for creating scenarios of operational game interactions

After formalization by the operational games theory some real-world game interaction (in salon game, in production and economic activities of enterprises and corporations, industrial complexes and sectors of the economy, in macroeconomic and geopolitical processes) you can start to study various possible scenarios of game interactions. It is necessary for the formation of the strategies of the operational side (of the player in whose interests research is conducted), optimal or rational in any sense, in various scenarios. This requires a methodology.

In a particular operational RD-game, a set of players is defined; a discrete time clock; a set of considered accounts (variables of the game's configuration space), actions, and operations. Operational gameplay refers to the game interaction of all or part of the players for a given period of time, during which players make choices during operations, accept and fulfill (or fail to fulfill) obligations, exchange information between them, and natural uncertainties are realized. What do you need to know in order to play analytically or imitatively a particular operational game process?

First, you need to know the initial balances (values) of accounts (variables) at the beginning of the considered segment of game interaction. Second – the initial characteristics of actions and operations: the parameters of the convolution functions and the sum functions of actions, which, if there are operator actions, can change during the game interaction, as well as the account balance. Third, it is necessary to use one or another hypothesis of the implementation of uncertainties in the course of game interaction, determined and modeled by probability distributions or otherwise. Fourth – for each player other than the operating party (the first player), it is necessary to make an assumption about his awareness and formulate a hypothesis about his strategy of behavior with such awareness, given in the General case in the form of synthesis. Knowing all this, we can conduct a simulation game simulation of this process, developing an optimal, in one sense or another, strategy for the behavior of the operating party.

This defines the methodology for modeling scenarios of operational game interactions. Operational game scenario modeling uses the concepts of "scenario condition", "full scenario condition", "scenario", and "scenario plan".

A scenario condition is any finite sequence of entries of the form (3), each of which can relate to any of the players or to the implementation of an undefined factor.

A full scenario condition is a scenario condition that determines the implementation of an indeterminate factor and the election of all players except one (the operating side).

A scenario is a combination of a complete scenario condition and the "optimal" (rational) strategy of the operating side when this condition is met.

A scenario plan is a set of scenarios of one of the players that describes all possible or practically interesting implementations of game interaction for this player.

Let us look at examples of creating scenarios for fairly simple operational game interactions.

Salon games, in most cases, are held in discrete time (by moves) and in a finite space of possible States of game interaction, and therefore are adequately modeled as ZD games. But in the case of, for example, poker, in which arbitrary money bets can be made, it is more correct to use the RC games considered in this paper.

In this case, the accounts (variables that describe the state of the game) will be:

- accounts of players 'available funds;
- money at stake;
- the state of the deck (at the beginning of each draw-one of 54! possible locations of cards in the deck, then – one of the factorial of the number of remaining cards in the deck);
- the state of the card sets in the players 'hands and the binary States of the players themselves (in-game or out-of-game).

Possible actions include:

- moving money from players to the pot at stake (an action with one sum equal to the amount of money being moved);

- moving money from the Bank to players (also a single-sum action);
- player exits from the current game;
- move cards from the deck to players during the initial distribution of cards to players in the draw;
- players taking a certain number of cards from the deck determined by the rules;
- players discard a certain number of cards from their own set of cards.

Possible operations include:

- individual operations of players related to depositing money in the Bank, replacing cards with cards from the deck, and withdrawing from the current draw;
- shuffle the deck before drawing;
- distribution of cards to players at the beginning of the draw;
- issuance of the Bank based on the results of the draw.

Multitudes of decision-makers, functions, convolution, vector controls, sets of action operations are defined the obvious way. Uncertainty is present in one operation – in the shuffle of the deck before the start of the draw. This operation itself can be modeled as having an empty set of LPR and consisting in an indefinite choice of one of 54! variants of the deck state under the influence of natural factors. But it can also be modeled differently, both by the operations researcher and by the players themselves, based on certain (possibly mystical) ideas about this process.

Players ‘awareness is determined by the rules of the game (which are different for different types of poker).

To form a complete scenario condition in each draw of such a game for one or another player means to make certain assumptions about how the deck was laid and what other players have in their hands, what amounts other players have and what strategies their behavior in the game is. These assumptions can include (and usually do include) probability distributions. Developing their own strategy of behavior, the player can strive to maximize the mathematical expectation of their own winnings.

When modeling the game interaction between a seller and a buyer in the market (for example, several types of fruits and vegetables), we will have to consider as accounts the wallets of the buyer and seller and the availability of all types of goods sold by both of them. You also need invoices describing the quality of each product. Players ‘interests can be described in one or multiple criteria. The seller is usually better informed about the quality of the goods than the buyer. During the bidding process, information is exchanged about the prices offered by participants, the availability and quality of goods.

In more complex game interactions associated, for example, with the production and economic activities of enterprises and corporations, industrial complexes and industries, the set of players, accounts, actions, and operations is significantly expanded. The variety of options for awareness and strategies of player behavior, risks and uncertainties, of course, becomes much richer. But the proposed formalism for describing operational game processes can withstand this as well.

5. Opportunities for development and application of operational games theory

The class of operating game models is original. Its novelty is due to the fact that

- the original formal definition of the operation is used, specifying the definition proposed by Yu. b. Hermeyer: "a set of targeted actions";
- unlike traditional multi-step games, in which one static game is played at each step, in which all players participate, in operational games, an "ensemble of static games" is played at each step;
- possible resource conflicts between static ensemble games are resolved using the "regulatory rule".

The proposed concept of operation is very flexible. The vast majority of actions that we do, in fact, either change some variables that formally describe the external world, or teach us something, improve the technologies at our disposal. This is how operations are defined above.

It is quite clear at the qualitative level that such operations can naturally be enlarged and detailed. In this connection, the question arises about the formal definition of the consolidation and detailing of operations, as well as about the formal definitions of the Union and decomposition of the players themselves. There are also many other fundamental questions related to equilibria and the analysis of the information structure in operational games.

At the first stage of testing operational game scenario modeling on solving applied problems, both micro-and macro-economic problems were considered. In terms of decision support for the management of production and economic activities and the development of enterprises and corporations, operational game models were developed and used that allow for What If analysis of a wide variety of scenarios for managing these activities with different implementations of exogenous factors [15, 16, 20, 21]. In the process of modeling the functioning of the Moscow industrial complex, scenario forecasting of the dynamics of the main indicators of the development of this complex and its branches was carried out [16, 18, 19]. We also built operational game models of a macroeconomic nature designed for What If analysis of national economic development management and modeling of geopolitical processes.

Developing this area of research, it is advisable to adjust the existing paradigm of economic and mathematical modeling. It is reasonable to replace the monetarist description of rational behavior of agents (players) as the desire to maximize profits with the natural desire of existing micro - and macro-agents to maximize total assets, including net assets and reasonable estimates of available human (taking into account the levels of health, skills, education) and natural resources. In legal terms, it is advisable to restrict operations that reduce the total assets of the planet as a whole.

6. Conclusions

The theory of operational games and the methodology of operational game scenario modeling based on this theory have proved to be a workable tool for adequate modeling of both micro-and macro-economic processes, collective and social interactions of a wide range. In this connection, there are very promising areas of fundamental and applied research. This tool allows us to talk about creating a new generation of platforms for generating information and analytical decision support systems.

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