Model of Organizational Behavior in a Hierarchical Structure

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Abstract. Interaction between persons performing operational activities within hierarchical organizational structures depends upon their mutual perception. Since certain aspects of mutual perception are poorly measurable, it is required to apply simulation methods. The purpose of this study is to elaborate an agent-based model of the hierarchical structure involving persons, whose behavior is described in the concept of mutual perception previously formulated by the author, but also to carry out a simulation exercise that determines the correlation between mutual perception of agents and group productivity of operational activities.

The simulation exercise also concluded that provisions of the concept of mutual perception within the hierarchy remain valid, namely, those stipulating that behavior of agents is consistent with phenomena specific to organizational behavior: if operational commands are being issued on the basis of mutually positive relationships between superiors and subordinates, group productivity increases.

The tool developed (an agent-based model with its code and documents that are publicly available) can be used in further studies on organizational behavior within hierarchical structures.

1. Introduction

Research into the problems of interpersonal compatibility and interaction within minor groups is conducted in the following studies: (Tajfel, 1972), (Abric, 2008). Building upon this theoretical framework and the findings of the studies on social influence phenomenon (basic works here are: (Tajfel, 1972), (Tajfel & Turner, 1986), (Turner & Oakes, 1986), (Turner & Oakes, 1989), (Worchel, 1998a), (Worchel, 1998b), (Bales, 1999)), as well as upon the empirical methods of observation of certain organizational hierarchy structures belonging to both private sector and public administration, the studies (Smarzhevsky, 2018a), (Smarzhevsky, 2019) formulated theoretical assumptions explaining the substance of mutual individual perception within the hierarchy. The essence of the concept is as follows: person that holds a position within the hierarchy reflects in his or her mind or, in other words, perceives other persons that occupy positions in the same hierarchy. At the same time, a considerable part of perceptions of person B intrinsic to person A are exhaustively covered by three aspects: individual (personal) perception, social perception and professional perception. These aspects can't be reduced to one another.
The purpose of this study is to carry out a simulation exercise and to analyze its results, while elaborating an agent-based model that describes the hierarchical structure performing operational activities. Positions in this structure are held by persons (agents), whose behavior is described by the concept of mutual perception. The experiment examines the behavior of individuals and groups, while establishing a linkage between mutual perception of agents and group productivity of operational activities.

2. Materials and method

The reason why the research uses simulation methods lies in the fact that values of social and psychological characteristics of persons and their mutual perceptions are poorly measurable. The natural way of research is to reproduce the processes of interaction between persons that hold positions in the hierarchy using various technical means. Such means are those of simulation modeling.

General approaches to agent-based modeling are contained in the following papers: (Furian, et al., 2015) (a conceptual approach to agent-based modeling on the basis of tools representing hierarchically organized control systems), (Garcia-Magariño, et al., 2017) that describes techniques of simulation modeling and on-line systems of decision-making under conditions of uncertainty, (Xiong & Pu, 2019) that involves model building on the basis of agent-action diagrams. The latter is close to the Agent-based model Analysis using Causal Discovery presented in (Janssen, et al., 2019). This study develops the algorithm of constructing an integrated causal graph of model parameters, which makes it possible to find emergent characteristics of models being analyzed.

Simulation models of managerial decision-making in an organization are described in the following publications: (Takahashi, 1997),(Ashworth & Louie, 2002),(Bendor, et al., 2001),(Fioretti & Lomi, 2008),(Troitzsch, 2008),(Inamizy, 2009a),(Inamizy, 2009b),(Fioretti & Lomi, 2010),(Thorbjorn, et al., 2012). These works reproduce the process of decision-making in a situation when there is an incoming stream of "problems" characterized by a quantitative attribute, the value of which defines the complexity of addressing those problems, and when associations of decision-makers are unstable. The main outcome of these studies was to confirm the fact, that the type of organizational structure has a significant impact on types of managerial solutions.

Research on communication and administration styles within an organizational structure is carried out in the following model: (Bela, et al., 2018). Individual characteristics contained in the Big Five model and their impact on adaptation of businesses on the market are described by the model presented in the following research paper: (Bajwa, et al., 2017). Group dynamics within teams of individuals united by strategic goals are examined in (Penagos-Londoño & Ruiz-Moreno, 2019). The work (Farsi, et al., 2019) uses modular hybrid simulation techniques to develop a model that would describe behavior within complex production systems.

The agent-based model presented in this study was developed by means of the NetLogo simulation modeling environment (Wilensky, 1999). Initial data for the present study were provided by the concept of individual mutual perceptions of people (Smarzhevsky, 2018a), but also by methodological and instrumental principles of simulation modeling within an operating hierarchy where staffing decisions are made (Smarzhevsky, 2018b).

To develop a new scientific knowledge, the study used the methods of algorithm development and coding in the NetLogo programming language. Besides, simulation exercise and analysis of its results were carried out.

3. Results

The "world" of the model (Fig. 1) represents a two-level hierarchical structure consisting of positions of heads and operators. Agents operating within the model are persons that hold the above-mentioned positions. Persons have a certain level of operational productivity and their mutual, but in this case individual, perceptions. The value of mutual perception of agents is given as a normally distributed random value, the parameters of which are set by means of interface controls.
Positive perception of person B by person A corresponds to a positive numerical value, while negative perception is in line with a negative value, expressed in specific units on a scale from sympathy to antipathy. Values of perceptions are put in order, which means that agent's A numerical value equal to +2 stands for a more positive perception of the agent B than the numerical value equal to +1.

![Figure 1. Environment (world) of the model objects.](image)

Existing in the world of the model that represents the space of perceptions, agents implement two strategies: getting close to agents perceived positively and retreating from those who are perceived negatively. The model allows agents to implement both, one or none of the strategies, which fixes the agent in the space of perceptions. Strategies of getting close/retreating are implemented in respect of other agents within the radius of agent's perception specified by the PerRadius variable.

Heads on the upper hierarchy level build up their own teams (groups) of operators that hold lower positions in the hierarchy. Operational productivity of each group (calculated as the sum of weighed individual productivities of operators belonging to the group on the basis of the distance between operators and group's head) varies according to agent's position in space. Individual productivity is given as an evenly distributed random value on the scale from 0 to 100. At any given time period, an operator can be a part of only one head's group.

At every moment of the modeled time in the course of simulation exercise, the head can form a group in different ways: 1) from agents within the reach of the manager at a given time (the radius is specified by the value of the Op_Radius variable), 2) from agents that are not subordinate to other heads, 3) and from those who are perceived negatively or/and positively by the head. In the model,
it is possible to implement both, one or none of the rules indicated in paragraph 3), which would mean that heads refuse to build up teams. Heads aim at maximizing overall productivity of their groups.

Showing their individual dispositions, operators are able to withdraw from their head's group if their attitude towards the head is negative. It might be done with a certain probability specified by the value of the PrbltyOfDecisn% variable. Heads are trained during simulation exercise: they remember operators who were included in their groups, but then withdrew. Such subordinates appear on the list of "not allowed" and are no longer included in the group. If the group consists of at least two operators, heads tend to exclude from it operators with the lowest individual productivity, and then they try to find another one with a better productivity.

The model provides an opportunity to change the values of perception and reachability radii in the course of the exercise, update individual perception values of the totality of agents, invert agent's perception by adjacent agents within the radius of perception and change the values of probability of operator's decision to withdraw from the group. It is also possible to change the set of relocation and enrollment strategies through interface tools. There is an opportunity to add the chance factor in relocation of agents using the Stoch_Motion_Speed variable. Model controls are presented in the Figure 2.

The existence of other agents currently perceived by each of them is shown by gray links, operators are indicated by blue figures, heads - by red ones. Their belonging to each other is shown by red links.

Figure 2. Model controls. Variation in the number of agents or heads, changes in radii or speed of random relocations, choice of behavior and group formation strategies or probability of exclusion of the least productive operator are shown in the left part of the figure. Probability of operator's withdrawal from the group, parameters of normal distribution, update and inversion buttons for the values of perceptions are shown in the right part of the figure.

Model, its code and accompanying documents are published and publicly available on the website www.comses.net (Smarchevskiy, Organizational behavior in the hierarchy model" (Version 1.1.0).)

Simulation exercise is intended to carry out research into the dynamics of changes in the composition of groups and to establish a linkage between quantitative perception indicators and total group productivity.

4. Discussion
Simulation exercise revealed that, given certain values of normally distributed parameters of mutual perception (N = -2, -3), there is an emergence of cyclical structures. They represent spatial arrangements of agents with variations in coordinates of some of the agents and in group productivity of separate groups (Fig. 3, Fig. 4). Appearance of such structures precedes a complete
stabilization. Otherwise, in case when the value of mutual perception radius exceeds a certain level increasing in line with growing number of agents within the model, volatility might persist for an unlimited period.

Stabilization occurs in the period of time from 200 to approximately 2000 units of modeled time. Time for stabilization depends on the number of agents, perception and reachability radii, but also on the speed of relocations of agents when implementing their individual strategies.

**Figure 3.** Stabilization in the form of cyclical movement (left circle) and of oscillation along a straight line (right oval). 53 operators, 7 heads, medium perception value is equal to -2, and standard deviation is of 8 points.

**Figure 4.** Dynamics of group productivity for the exercise from the Fig. 3.
Simulation exercise concluded that provisions of the concept of mutual perception within a hierarchy performing operational activities remain valid: values of mutual perceptions represent factors defining the composition of groups and the value of group productivity under equilibrium conditions.

5. Conclusion
The results obtained confirm the validity of the mutual perception concept: behavior of agents is corresponding to phenomena observed in organizational behavior: if operational commands are being issued on the basis of mutually positive relationships between superiors and subordinates, group productivity increases.

Besides, the results obtained scale up the approach used to study both the types of interaction among employees of service companies that perform operational activities and their impact on organizational behavior. The approach was presented in the following papers: (Gwinner, et al., 2005), (Mathwick & Mosteller , 2016),(Sumaneeva, et al., 2018) and (Zizhen, et al., 2018).

The tool developed might be used in further research into organizational behavior within a hierarchy under the concept of mutual perception. The model, when modified, allows including of social and professional aspects of mutual perception, reproducing the process of operational activity with these factors in mind, as well as creating a matrix of mutual perceptions (Smarzhevsky, 2019), thus setting initial operating conditions for the hierarchy.

In so doing, the results of the study and the above proposed scientific tool (ABM) can be considered as scientific novelty and might be used for further research into organizational behavior within hierarchical structures.

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