PREDICTING MODELING OF MANAGEMENT INTERACTION: ATOMISTIC APPROACH

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Abstract

In this paper for the first time the new atomistic approach for predictive mathematical modeling of social and psychological phenomena and processes was presented for the first time. The nearest possible fields of application were noted. Among of them there are organizational psychology and problem of effective management teams and providing the quality administrative interaction. The effectiveness of the new approach was demonstrated on the example of predicting the partial destruction of the bonds between graphene structure atoms. The essence of the prediction is to analyze the stress distribution in system subjects. Stresses are calculated by the original methodic with application of energetic function that describes interaction of neutral atoms.

Key words: atomistic approach, predictive mathematical modeling, management interaction

Introduction

For the first time methods and approaches of mathematical modeling were began to be used in psychology in the end of XIX century, and in the middle of XX century they have already came into wide use. Social psychology admitted approaches that applied abilities of physics and mathematics – field theory of K.Levin [1] and sociometry of J. Moreno [2].

The premises to active implementation of mathematical modeling for description of social systems and processes patterns were appearance of electron and calculating systems and wide spread of sociological, social and psychological investigations. Construction of mathematical model should be guided either common principles of mathematical modeling or features of investigated problem and specifics of applied mathematical apparatus. Among the most sought classical mathematical model used in psychology there are following classes:

- Models on the base of multidimensional differential equations [3];
- Models on the base of difference equations [4];
- Models on the base of stochastic differential equations of Langevin and Ito-Stratanovich [5];
- Models on the base of mathematical apparatus of cellular automata [6]
- Models on the base of mathematical apparatus of the catastrophes theory [7]
- Models on the base of self-organized criticality theory [8]
- Models on the base of the analysis of systems with chaos and reconstruction of the stable states on the time series [9]

At the same time canons that build mathematical models of social systems and psychological processes can significantly differ from the basic principles of building models used in the natural sciences. It is caused by the fact that for social objects it is often difficult to find relations and patterns that allow to connect characteristics of all systems with individual characteristics of composed elements as well as mechanisms of its interaction.

To date one of the prospect directions in social systems and psychological process modeling is multiagent approach [10]. Feature of this approach is possibility of investigation of social system (group) properties taking into account all composing parts and mechanisms of its interaction. The conceptual base of this approach is to replace the real objects of the social system (group) with specific range of properties

by computer analogs-agents in virtual environment interacting between themselves and with environment due to the same laws as in real system.

Nonetheless, the made critical analysis of existing scientific papers devoted to application of mathematical modeling for description of the psychological phenomena in social environment showed that none of applied approaches doesn't allow to predict possible changes in behavior of social group in different time moments taking into account the influence of all external factors. Mathematical model that allows to provide full analogy between selective psychological categories and conventional physical and mathematical terms is required. Due to this model researchers will have new effective tool that will allow not only to describe behavioral template in each considered social group but also to predict possible changes inside the group that causes by determined external factors.

The target of this work is the presenting of the new atomistic approach for predicting modeling of social and psychological phenomena and processes and, in particular, mathematical modeling of management interaction in different organization environments (spaces/fields).

To achieve supplied target the following tasks will be solved:

1) to give short characteristic of psychological approaches to description of intergroup interaction that use mathematical methods;

2) to explain base states of atomistic approach to mathematical modeling of social and psychological processes and phenomena (in organizations);

3) to analyze common possibilities and advantages of atomistic approach to predictive modeling of social and psychological phenomena and processes in comparison to presented earlier.

Psychological approaches to description and analysis of group interaction

In psychology there is an array of approaches to investigation of group process. In the context of our investigation the biggest interest is caused by sociometry of J. Moreno and field theory of K. Levin.

To diagnose interpersonal relationships J. Moreno developed sociometric test that allowed to obtain data of three types: to estimate the degree of unity-disunity in the group, to estimate the position of personality in group by the scale «leader-spurned» and to reveal subgroups in group. To do it Moreno turned terms «attraction-repulsion» into terms «choice-rejection» that can be measured quantitatively. Testing is conducted in the form of survey. Members of group fill cards and answer the two questions (for example, «Whom would you asked for help first of all?» and «Whom you wouldn't ask for the help?»). The procedure has two versions: non-parametrical (number of variants is not limited) and parametrical (number of variants is limited to 4-5 in the group of 22-25 persons).

With the group size of 12-16 persons analysis of bonds between members is possible just due to computing technology. «Obtained choice» and «given choice» are distinguished. Sociometric constant (N-1) is saved just for the system of obtained choice (from group to member). For the system of given choice (from member to group) sociometric constant is measured by value d (sociometric limitation). Introduction of this value provides standardization of external conditions in groups of different population. To do it we determine value d due to same for all groups random event probability calculated by formula $P(A) = d/ (N-1)$, where P is random event (A) probability of sociometric choice, N – number of group members.

Filled sociometric cards are quantitatively treated. Initially sociometric matrix (table) is built, sociogram (graphic picture of members reaction on each other) is built on its base. After that index of sociometric status of group member is determined by the formula:

$$C_i = \sum_{i=1}^{N} \left(R_i^+ + R_i^- \right), \quad (1)$$

C_i – sociometric status of i-th member, R^+ and R^- are choice obtained by i-th member, N – number of groups members.

Corresponding formulas are used further to account index of group i-th member emotional expansiveness, index of group emotional expansiveness, index of psychological reciprocity [2].

In the base of K. Levin theory there is a metaphor of electric and magnetic field. «Field» is understood as «vital space» of personality or group that includes the group itself and surrounding environment (as it exists for the group). Each behavior and all its manifestations (action, evaluation, thinking, etc.) are understood as change of field state in unit of time: dx/dt.

According to Levin, investigator's task concludes in development of theoretical constructs, methods of observation and measurement that allow «to characterize the properties of any given living space at any given point in time and to formulate laws governing the change of these properties» [1, P.11].

K. Levin introduced single mathematical apparatus and built mathematical model which base is concepts of force, stress, distance, barrier, locomotion. Describing his theory he said: «Probably field theory is better to describe as a method, namely, method of causal links analyzing and building scientific constructs» [1, P. 66].

Thus, in psychological investigations of group processes there are established approaches that use physical and mathematical methods for diagnosis and prognosis of group processes. At the same time, development of either psychology or physics and mathematics opens new possibilities for improving methods for solving tasks of predicting mathematical modeling of group processes.

Atomistic approach to predictive modeling of socio- and psychological phenomena and processes

This paper suggests a new approach to predictive modeling of psychological phenomena and processes occurring inside of social group. Theoretical base of approach is physical and mathematical conception of atomistic modeling [11]. Due to this conception human society, collectives and groups are considered as atomic structure. In Fig.1 there is the fragment of atomic mesh of recently opened new 2D-crystall – graphene [12]. In Fig.1 atoms are displayed by black circles, chemical bonds between atoms are determined by the lines (under chemical bonds we understand covalent interaction between atoms that determines topology of a given structure). Let's note that except covalent interaction of each atom with three neighbors there is the interaction of each atoms with all – van der Waals interaction. Difference between to interactions lies in energy. Energy of chemical (covalent in this case) interaction amounts several electron volts when van der Waals energy – tenths.

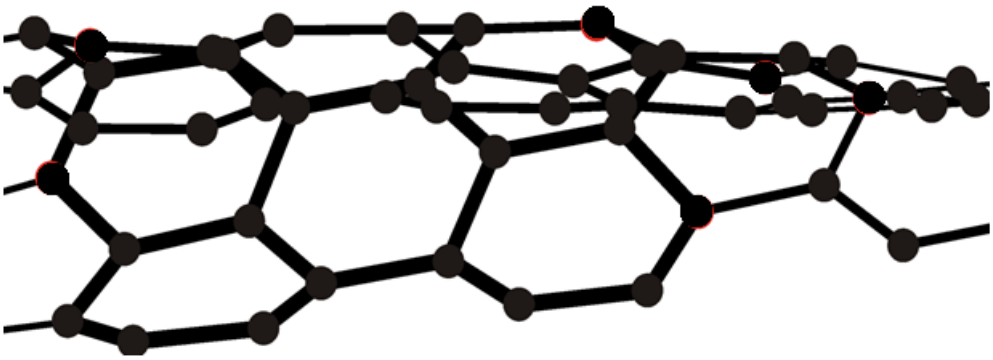


Figure 1. Fragment of graphene atomic mesh.

Similarly to graphene where each atom interacts with all others in various degrees, man in his collective is a quantum – minimal unit of considered social and psychological structure. In this case, there is the analogy of man with atom, social

and psychological structure – with atomic structure of certain crystal system. Let's note that if collective is small, it can be compared with nanocrystall, or molecular formation, or cluster that have finite number of atoms.

Relationship between two people in collective can be described similarly to two neutral atoms in atomic and molecular system. Graphically this relationship can be presented as shown in Fig.2 (in X-axis distance in dimensionless units, in Y-axis – interaction energy). Here R_0 – effective distance (from physical point of view), namely, distance at which two subjects interact favorably that implies the most effective interaction from the position of result. This distance corresponds to energy minimum E_0.From physical point of view, the less energy, the closer this system to the stable ground state. Energy minimum corresponds to system ground state, i.e. the most stable that is noted by the letter A. Also here R is interaction distance, E – interaction energy.

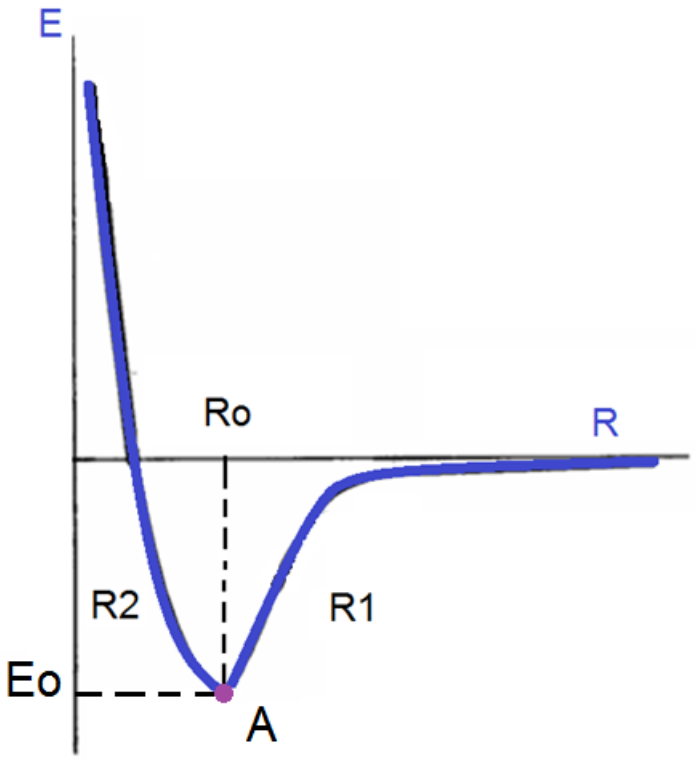


Figure 2. Energy of interaction between two neutral atoms profile.

Suggested approach distinguishes two significant moments in the development of relationship between two people inside of each social group: 1) degree of relationship in given moment completely satisfied both sides (in Fig. 2 it corresponds to location of point A); 2) interacting sides have a desire to become closer – field of values R1 that corresponds to interval (Ro;+∞); 3) interacting sides have a desire to move away – field R2 (0; Ro).

Further our reasoning fully corresponds to interaction of atomic and molecular system components. According to this reasoning each of social group members has his «own energy», or energy potential E_i (index i notes a member of group). This energy potential is determined by degree of effectiveness of relationship between men in group and can be calculated as «interaction energy» of a given group member I with all other j ($1<j<N$, $j\neq i$, N – amount of group members). The less this value the more productive interaction. Herewith, in each stage of relationship change conservation of energy law must be carried out. Conservation of energy holds integrity and normal operation of considered social group.

Calculation of i-th subject energy potential is carried out by well-known formula applied to calculation of neutral atoms in system interaction energy [13]. In common case energy E_i can be presented as the sum of two energy terms – repulsive potential (V_R) and attractive potential (V_A):

$$E_i = \sum_{j=1,\, j\neq i}^{N} \left(V_R(R_{ij}) - V_A(R_{ij}) \right), \qquad (2)$$

where R_{ij} – distance between system subjects i and j.

Noted potentials can be set by different functions, main is the correct reproduction of energy potential dependence on distance as shown in Fig.2. Attractive potential V_A between atoms i, j in molecular and crystal systems matches to occurrence of first contact between strangers in collective, when information is absent and relationship are built at intuitive level. As a result, people, one way or

another, are attracted to each other because they are forced to look for ways of interactions being in one collective. Rapprochement between subjects can be characterized as increasing of attractive energy V_A by absolute value. As a result of such rapprochement subjects will achieve maximal favorable state in relationship that will correspond to reaching distance R_0 within atomistic approach. From physical point of view such relationship corresponds to effective distance between system's atoms when atoms don't attract and don't repulse. In this condition without outside influence system can stay indefinitely.

Repulsive potential V_R corresponds to the interaction type that leads to sharp repulsion. From physical point of view it means too big rapprochement. From the view of personality it corresponds to "step across line" in communication that inevitably leads to the aggravation of relations, i.e. to increasing of interaction energy. *We recall that any increase in energy signals about various impairments of system, which goes into an excited state as a result.*

This paper suggests to apply potential of Lennard-Jones to calculate Ei with account of described above E_0, R_0 [14]:

$$E_i = \sum_{j=1,\, j\neq i}^{N} \left(4E_0 \left(\left(\frac{R_0}{R} \right)^{12} - \left(\frac{R_0}{R} \right)^{6} \right) \right). \tag{3}$$

On the base of described approach predictive mode is suggested. Its idea concludes in the calculation of local stress field, i.e. stress experienced by each individual in the team. Value of stress P_i, experienced by personality i is introduced like difference between volumetric energy densities [15]:

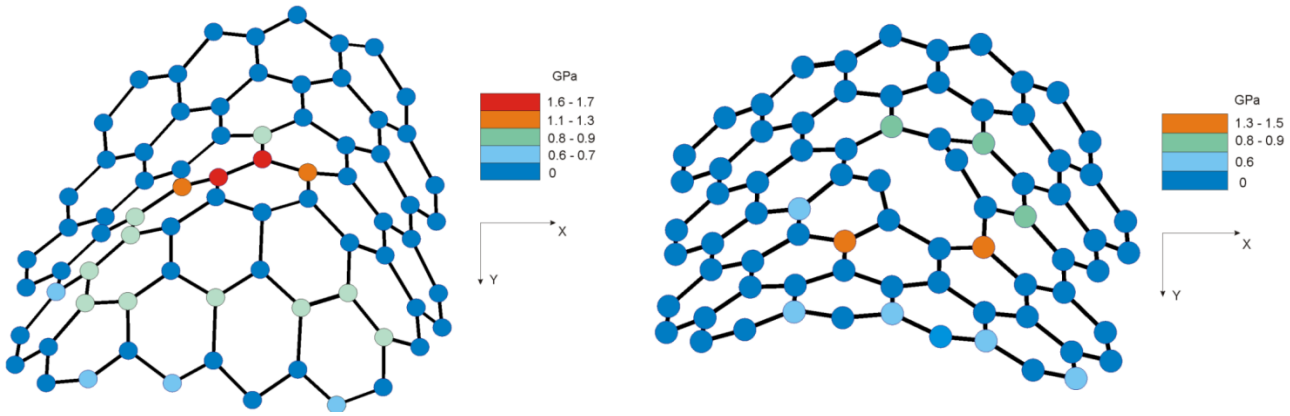
$$P_i = \left| w_i - w_i^0 \right|. \tag{4}$$

Here w_i is volumetric energy density calculated as energy E_i per unit volume that characterizes subject state at the moment. Another value w_i^o is volumetric energy density that corresponds to ground state of system, i.e. the most effective state. Thus, after calculation of given system (collective) stress it is possible to get information: 1) about system state at the moment with estimation of the most stressful parts (stressful relatively to entire group); 2) about possible phenomena that can occur in system in nearest future. Parts of system (one subject or group) where stress is higher relatively to another can be considered as pockets of possible conflicts that can lead to destruction of system, i.e. to disintegration of group or to loss of single members.

New possibilities of atomistic approach in diagnosis of management interaction

Application of atomistic approach to design of predictive mathematical model has a big potential in social and psychological investigations of management teams and management interaction that generates organizational culture. Organizational culture is «vital space» or field where subjects of common management activity interaction is carried out [16].

Management teams are usually goal-oriented. Subjects of common management activity interaction has non-personal (business) nature and has strongly pronounced criterion for success in the view of achieved goal and obtained results. Since results of team management interaction affect either people (members of organization, partners and clients) or material resources of organization, the task of determination of possible problems in the process of team management interaction becomes very important.



a b

Figure 3. Demonstration of predicting modeling on the example of graphene atomic mesh.

Atomistic approach opens possibility to make prediction of team members' behavior development and the effectiveness of the team work. Effectiveness of team work, possible downs in the work and conflicts will be determined on the base of stress map. Let's demonstrate predictive possibilities of atomistic approach on the example of partial destruction of atomic mesh in the result of high stresses on separate atoms. Fig. 3a shows distribution of stresses in graphene atomic mesh. Color shows value of stress that is measured in gigapascals. Analysis of stress distribution allows to immediately set that there are two atoms that have the biggest stresses, maximal for given system. In the surrounding of these two atoms increased values of stresses are observed too, further it decreases to zero. On the base of this map it can be suggested that exactly in this field of system partial destruction of atomic mesh is possible. To check our predictive modeling we calculated the same system with one destructed bond – between atoms with maximal stresses (atoms that noted by red circles). If energy per one atom decreases it means that system with destruction of this bond went to more favorable on energy state (herewith energy decreases. i.e. systems turns to more favorable state).

The result is shown in Fig. 3b. Stress map shows that atoms with maximal stress earlier practically don't have stress after bond destruction. It is clear that the maximal stress in system decreased from 1.7 to 1.5 GPa. Thus, our prediction on the

base of stress map analysis was right. Similarly it's possible to build stress maps of every people group and to predict work effectiveness, possible events, conflicts occurrence and to determine conditions when team work will be the most effective.

Conclusion

This paper presented new atomistic approach to predictive mathematical modeling of social and psychological phenomena and processes. We noted the nearest field of its application – organizational psychology and problems of effective management teams' construction and providing qualitative management interaction between teams' members.

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