Analytical and Instrumental Framework for The Analysis and Resolution of Stakeholder Interest Conflict Using Cognitive Maps

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Abstract. The statement of the basic control problem of a situation with many active stakeholders using cognitive maps is presented. Approaches to the analysis and resolution of interest conflicts in such situations based on the basic control problem are proposed. These approaches make it possible to take into account different interests, identify contradictions and, if possible, find ways to overcome these contradictions by choosing different strategies for interaction between stakeholders. The problems systematization of conflict analysis and control in such situations at different phases of the conflict is presented. The systematization purpose is to organize monitoring, analysis and control of conflict situations using cognitive maps and scenario modeling tools based on them.

1. Introduction

Modern interdisciplinary, ill-structured (geopolitical, socio-political, environmental, etc.) decision-making situations are characterized not only by high changeability, uncertainty due to limited knowledge about the situation and interaction of many heterogeneous factors. Stakeholders with different interests and/or with a different understanding of the situation are often associated with an objective problematic situation. In addition, the stakeholders have different possibilities of impact on the final result of their interaction, which leads to the development of conflicts generated by the struggle of stakeholders for spheres of influence. To solve problems in which the presence of different interests in the same situation, the peculiarities of the different stakeholders’ views on the situation and the difference in these views are part of the problem, we propose to use cognitive maps (or fuzzy cognitive maps).

The cognitive map (CM) has found great applicability in diverse scientific and applied domains for modelling and providing decision making support in interdisciplinary, ill-structured situations [1-3].

The CMs reflect the structure of the causal influences between the significant situation factors generated as a result of the translation of the mental (or cognitive) representations and beliefs of people into a formal language. Thereby they allow the use of formal methods (for example, simulation) [4]. Finally, they are fuzzy because when assessing the interrelation between situation factors, uncertainty (confidence) of causal interrelation is estimated [3]. In a situation with many stakeholders, the CM reflects the stakeholder interests and goals, vision of possible stakeholder impacts on the situation in the context of achieving their own goals.

At the same time, the typical problem of resolving a certain problematic situation is widespread ([5, 6], etc.) by (I) building an of a generalized and concerted representation about the situation (based on individual perceptions of stakeholders) in the form of a CM; (ii) structural analysis of the properties of the CM situation and scenario modelling of the possible development of the situation in order to ensure a balance of
stakeholder interests (in this case, the choice of the scenario should be based on the consensus decision of the stakeholders).

Our approach to the problems of analyzing and controlling a situation with many stakeholders differ both in the research subject and in the means of studying such situations. The subject of the research is the conflicts of stakeholders, strategies for the development of the conflict based on the reflection in the CM of the stakeholders’ activity areas (their interests and control levers) in their relationship through the structure of causal influences of situation factors. This expands the range of different problem statements for conflict analysis and control. We also use CM structural analysis and scenario modelling to solve such problems. However, our approach to structural analysis differs from the typical practice of such CM analysis. In typical practice, CM analysis relies on various structural indicators borrowed from network analysis ([5,6], etc.) – the number of factors, N, of connections, C, the connectivity of factors – C/N, the number of input (transmitter) and output (receiver) factors, density C/N (N-1), etc. Our analysis takes into account the dynamic parameters of the factors of the situation, which makes it possible to identify potential control factors hidden in the complex structure of CM and contributing to the achievement of goals. The CM analysis includes (i) determining the cumulative influences of potential control factors (their changes) on goal factors; (ii) determining the weight and character of the cumulative influence of any control factor on the desired dynamics of goal factors; (iii) an assessment of the potential control factors efficiency, which is useful for ranking them according to the degree of influence on all or some of the target factors [7].

The results of the analysis (I) make it possible to assess the potential for achieving the stakeholder goals with different strategies of their interaction and (ii) serve as the basis for the formation of various scenarios for a conflict development in various modelling modes (direct or inverse control problem). The paper briefly presents the analytical, methodical and instrumental framework of the proposed approach to the analysis and resolution of the conflict of active stakeholders.

2. Statement of A Basic Control Problem of The Stakeholder Situation

2.1. Statement of A Control Problem

Let $K'(X,W,f)$ be a CM of the situation $S$ characterized by the interaction of different active stakeholders, $\{AS_i\}$, interested in changing the situation regarding their own goals, in which $X = (x_1, ..., x_n)$ – situation factors set; $W = [w_{ij}]$ – matrix of influences’ weights between factors; $f$ – a function of changing the value of arbitrary factor at time $t$, $t = 0,1,2,...$ :

$$f : x'^{t+1}_i = x'_i + \sum_{j \in I_i} w_{ij} \cdot \Delta x'_j + g'_i,$$  

(1)

where $x'_i$, $x'_j$ – activity level $x_i, x_j$ at the moment $t$, $\Delta x'_j = x'_j - x'^{t-1}_j$, $w_{im} \in [-1; 1]$ – the influence weight of $x_j$ on $x_i$, which characterizes the level of CM builder confidence that a change in activity $x_i$ is the cause of a change in the activity $x_j$, $I_i$ – a set of numbers of $\{x_j\}$ connected to $x_i$, $g'_i = g^0_i$ for $t=0$ and $g'_i = 0$ for $t\neq 0$; $x^0_i, g^0_i \in [-1, 1]$. Equation (1) in matrix form $x(t+1) = (E_N + W)x(t) - Wx(t-1)$, where $E_N$ – a unit matrix. If $Q = \lim_{t \to \infty} Q' = (E_N - W)^{-1}$ then $X'^{t+1} = Q'^{t+1}X^0 + Q'G^0$ is valid, where $Q' = E_N + W + W^2 + ... + W^k$, $G^0$ – a vector of external impacts on factors at $t=0$, $W^k$ – a influences’ matrix to the $k$-th degree, $k=1,...,t$. Thus, $Q$ is the matrix of the integral (all direct and indirect) influences between factors in the map $K'$. For each stakeholder $AS_i$, are given (i) an interest area: goal factors $X^i_c \subset X$; (ii) an active control area: control factors (impacts) $X^i_u \subset X$; (iii) $R(X^i_c)$ is a vector of factors dynamics estimation, which sets
the desired directions of change in goal factors from the point of view of the \( A_S \), where

\[
R(x_i^C) = \begin{cases} +1, & \text{if the factor } x_i^C \text{ increase is favorable} \\ -1, & \text{if the factor } x_i^C \text{ decrease is favorable} \end{cases}
\]

Under such conditions, it is possible to set different problems' statements of the situation control: in the interests of an individual stakeholder (a basic statement) or a selected subset of stakeholders or all stakeholders of the situation. Interest areas and active control areas of the stakeholders \( \{A_S\} \) do not intersect each other, i.e. \( X^C = X \setminus (X^U \cup X^{other}) \), \( X^C = \{X_i^C\}, X^U = \{X_i^U\}, X^{other} \) — other factors of the map \( K^U \). Active control areas of the \( \{A_S\} \) form disjoint subsets of map factors, i.e. for any pair \( A_S \) and \( A_S' \), the condition \( X_i^U \cap X'_i^U = \emptyset \) is executed. In this case, the interest areas of individual stakeholders may intersect.

From the set \( \{A_S\} \) a main stakeholder \( A_S \) is selected, in whose interests the control problem of a change the situation is solved (within the framework of his goals \( X_i^C \)). We need to find factors \( U \subset \{X_i^U\} \) that influence the changes in the goal factors \( X_i^C \) (in accordance with \( R(X_i^C) \)).

We can specify the basic statement and the solution of the control problem of situation development in the interests of the stakeholder \( A_S \) in dependence (i) on the presence or absence of an interest conflict between active stakeholders; (ii) on the involvement of control resources of other active stakeholders in achieving of the development goals of the situation \( S \) in the interests of the stakeholder \( A_S \); an active control or a passive control.

A conflict of interest exists between the main stakeholder \( A_S \) and the stakeholder \( A_S', i = 2, 3,... \) if desired changes in \( A_S \) goals result in undesirable changes in \( A_S' \) goals when both parties are active.

To resolve the conflict in favour of \( A_S \), we propose a procedure for searching for such factors \( U \) from the activity areas of \( A_S, \{X_i^U\} \) and other stakeholders, \( \{X_i^U\} \), the impact on which contributes to the achievement of \( X_i^C \), taking into account the presence of a negative influence of control factors \( X_{neg}^U \) on \( X_i^C \) \( (U \cap X_{neg}^U = \emptyset) \). Moreover, the control can be active, passive and mixed. The active control, when the achievement of \( A_S \) goals is ensured only by exposure from the active control area of \( A_S \) \( (U \subseteq X_i^U) \); passive control, when active control areas of other stakeholders are involved \( (U \subseteq \{X_i^U\}) \); mixed control is a combination of active and passive control.

The problem is solved in the case of the existence of such \( U \), when the activation of factors from \( U \) contributes to the change in all \( X_i^C \) in accordance with \( R(X_i^C) \), and the total integral influence weight of \( U \) is higher than the total integral influence weight of \( X_{neg}^U \).

In general, the impact of factors \( U \) can contribute to the achievement of some goals from \( X_i^C \) or \( U = \emptyset \) (the case where the goals \( X_i^C \) cannot be achieved). These cases are explained by the weak influence of \( U \) in comparison with the influence of \( X_{neg}^U \) and/or the absence of counteracting factors to the \( X_{neg}^U \) factors.

The general scheme for solving the basic problem is presented in [7].

Based on the basic statement, we can consider the possibility of a situation change regarding the interests of each active stakeholder of the situation.

Further, based on the results of such analysis, it is possible to form various combinations of the stakeholders (e.g., the identification of stakeholders for the formation of a coalition, where the actions of each actor of the coalition contribute to the achievement of his own goals and the goals of the coalition partners, etc.).
2.2. Evaluation of the Possibility of The Goals Achieving of The Stakeholder

The goals of the interest area of the stakeholder AS, $X^C_1 = \{x_{1i}^C, x_{12}^C, ..., x_{im}^C\}$ are potentially achievable if for any goal factor, the total weight of positive influences is potentially achievable if for any goal factor, the total weight of positive influences $q_{iU}^{\text{pos}} + q_{iU}^{\text{neg}}$ exceeds the total weight of negative influences $q_{iU}^{\text{neg}}$:

$$q_{iU}^{\text{pos}} + q_{iU}^{\text{neg}} > q_{iU}^{\text{neg}}. \tag{2}$$

The total weight $q_{iU}^{\text{pos}}$ of the influences of the control factors from $X^U_i$ of the stakeholder AS, on his goal factor $x_{ik}^C \in X^C_1$ is equal $q_{iU}^{\text{pos}} = \sum_j q_{jk}^{\text{pos}}$ (the sum modulus of the integral influence weights), where $q_{jk}^{\text{pos}}$ is the weight of the integral influence of the control factor $x_{jk}^U \in X^U$ on the goal factor $x_{ik}^C$ (from the interest area of the AS). The total weight $q_{iU}^{\text{neg}}$ of the positive influences of the control factors $\{x_{pos_i}^U\}, x_{pos_i}^U \in X^U$ is equal $q_{iU}^{\text{pos}} = \sum_j |q_{jk}^{\text{pos}}|$, where $q_{jk}^{\text{pos}}$ is the weight of the positive integral influence of the control factor $x_{jk}^U$ on the goal factor $x_{ik}^C$. Accordingly, the total weight of the positive influences of the control factors $\{x_{neg_i}^U\}, x_{neg_i}^U \in X^U$ is equal $q_{iU}^{\text{neg}} = \sum_j |q_{jk}^{\text{neg}}|$, where $q_{jk}^{\text{neg}}$ is the weight of the negative integral influence of $x_{jk}^U$ on $x_{ik}^C$.

The required set $U$ includes those the control factors whose integral influences were taken into account in the calculation $q_{iU}^{\text{pos}}$ or $q_{iU}^{\text{pos}, -q_{iU}^{\text{neg}}}$ for each goal. Also, the necessary direction of change of each $u_i \in U, r_i(u_i)$ is determined [7].

In this case, the inequality (2) characterizes the general case where three groups participate of stakeholders in changing the situation $S$ in the interests of the stakeholder AS, (a variant of mixed control of the situation). The first group includes the stakeholder AS, whose control factors correspond to the active control of the situation $S$ in his own interest. The second group $\{AS_{pos}\}$ includes stakeholders whose control factors correspond to the passive control of the situation $S$ in the stakeholder AS, interest. Finally, the third group includes the stakeholders $\{AS_{neg}\}$ whose control factors prevent the situation $S$ change in the interest of the main stakeholder AS.

Depending on the involvement of various stakeholders in the solution of the problem, the desired set of controls $U$ can consist of different combinations of control factors of the stakeholders [7].

3. Methodical and Instrumental Framework for The Analysis and Resolution of The Conflict

3.1. Analysis and Resolution Conflict Schemes

Let us consider schemes for analyzing and resolving a conflict between two stakeholders based on the statement of control problem presented in section 2. A conflict situation arises when real contradictions are expressed in the confrontation between their carriers, who seek to prevent each other from achieving any goals, satisfying any interests or changing the views, opinions or positions of each other. Let the map $K^C$ (section 2) reflect the situation of interaction of three active stakeholders AS, AS, AS, whose areas of interest and control do not overlap (Figure 1).
We highlight on the CM two types of contradictions in interest (goals) areas. A unidirectional contradiction between two stakeholders $A_{S_1}$ and $A_{S_2}$, when the desired change in factors from the interest area $A_{S_1}$ entails an undesirable change in the factors from the interest area $A_{S_2}$, and at the same time there is no negative influence of the second on the first (or vice versa). Mutual contradiction in interests (goals) between two stakeholders, when a desired change in factors from the interest area $A_{S_1}$ entails an undesirable change in factors from the interest area $A_{S_2}$, and at the same time, a desired change in factors from the interest area $A_{S_2}$ entails an undesirable change in factors from the interest area $A_{S_1}$. The presence of contradictions between and form conflict areas on the map $K'$. 

Let's consider several approaches to defining the goals' vectors in interest areas in the stakeholder interaction and the formation of various scenarios for the development of the situation.

**Approach 1.** Formation of goals' vectors of outside the conflicting areas of interests of stakeholders. In this case, any goals' vectors chosen from these areas are consistent (there is no adverse influence on their achievement). Therefore, their interaction can be viewed as cooperation. Figure 2 shows the interaction scheme between $A_{S_1}$ and $A_{S_2}$ outside the conflicting areas of interest. White arrows reflect the activity of $A_{S_1}$ and $A_{S_2}$ in achieving their goals, while the dashed arrow means $A_{S_1}$'s indirect favourable influence on $A_{S_2}$'s goals.

**Approach 2.** Formation of a goals' vector of in the area of unidirectional contradictions. In this case, only one of the interaction parties, without affecting its own interests, can have a negative influence on the other interaction party. Such influence is latent for the second party since it is expressed indirectly: active control of $A_{S_1}$ to achieve its own goals indirectly leads to an adverse influence on the achievement of $A_{S_2}$'s goals (in Figure 3, the adverse influence is indicated by a grey arrow).
**Approach 3.** Formation of goals’ vectors in conflict areas of stakeholder interests. In this case, two strategies are possible that determine interaction during the development of productive and destructive conflicts, respectively. In a productive conflict, the conflicting parties find an opportunity to resolve it. Contradictions in interests and related goals are removed through compromises that allow the parties to find ways to resolve the conflict. A destructive conflict tends to expand and escalate and often ends with the victory of one of the conflicting parties.

Therefore, the main problem of studying a conflict in order to resolve it is to identify the factors that determine the conflict development along a productive or destructive path. The productive conflict development is possible by determining the goals vectors for $A_S$ and $A_S'$ from the factors included in the corresponding conflicting areas of interest, but not associated with contradictions (Figure 4).

![Figure 4. Schematic representation of the development of a productive conflict.](image)

Thus, a compromise is reached between the parties to the interaction, which consists in the fact that the area of interest is limited to consistent goal factors of each of the parties to the interaction.

The development of a destructive conflict is associated with the choice of such controls from the active control area of some stakeholder (to achieve their own goals), which would increase the negative impact on the achievement of his opponent’s goals (Figure 3).

Restraining the conflict development between the interacting parties can be achieved by choosing such controls from the respective areas of stakeholders’ active control, whose favourable influence neutralizes the negative influence of conflicting factors in the goals’ vectors from the interest areas of the interaction parties. In either case, substantial resources may be required (the levers of active control of each of the stakeholders must be sufficient to ensure the development of a destructive conflict in their own interests or to restrain the development of the conflict).

The proposed schemes for analyzing the interaction of stakeholders can also be used to form coalitions. Figure 5 shows the possibility of combining the efforts of $A_S$ and $A_S'$, which have no contradictions in their areas of interest, to confront $A_S$, with which $A_S$ has contradictions.

![Figure 5. Schematic representation of forming a coalition of $A_S$ and $A_S'$ against $A_S$.](image)

Regardless of the schemes considered above, the selected control vectors must be consistent with the goal vectors, which ensures the best effect from the chosen scheme of stakeholder interaction.
3.2. The Problems Systematization of Conflict Analysis and Control in Situations with Many Stakeholders at Different Phases of The Conflict

The presented statement of a basic control problem and related schemes of analysis and conflict management are focused on finding potential opportunities for resolving conflicts between stakeholders. Such problem statement is convenient when analyzing a problematic situation under a lack of exact information on control resources of stakeholders and predetermines further specification of the problems under various assumptions about possible strategies of interaction and resource constraints of the stakeholders in situation. To solve these problems, an approach to scenario modelling of conflict development has been implemented. The implementation includes (i) the problems systematization of conflict analysis and control, aimed at organizing monitoring, analysis and control of conflict situations when solving applied problems using cognitive maps and modelling methods based on them (Table 1) and (ii) the instrumental support for solving these problems.

Table 1. The problems systematization of conflict analysis and control at its different phases.

| Phase characteristic | Analysis problem | Control problem |
|----------------------|------------------|-----------------|
| Pre-conflict phase   |                  |                 |
| Latent contradictions in goals and interests | Identification and analysis of contradictions and their sources | The conditions' search for the transition to the conflict phase and the development of ways to prevent them |
| Conflict interaction |                  |                 |
| The manifestation of contradictions in the interests in the implementation of the declared actions by the parties not directly related to the conflict. | Various strategies analysis of the participants in the confrontation | Search of mechanisms to resolve the conflict or reduce the level of conflict, where possible. Scenario modelling of controlled development for analyzing the conditions of exacerbation of a conflict situation |
| The use of active aggravating and retaliatory actions |                  |                 |
| Post-conflict interaction |                  |                 |
| Coordinated formation of the exit plan from the acute conflict phase | Analysis of the opposing parties in conflict resolution | Synthesis of an optimal or acceptable strategy on the space of constraints in the choice of control impacts of stakeholders to minimize contradictions |

The instrumental support for solving the problems highlighted in Table 1 is a computer system for scenario modelling of situations (research project). Figure 6 shows a selective interface of the system. The functionality of this system supports the solution of a set of goal tasks for finding and substantiating strategies for solving problems in conflict situations, including analyzing the goals of the parties to the conflict; analysis of the resources of the parties to the conflict; analysis and justification of the possibilities of forming coalitions among the participants in the conflict; modelling of scenarios of interaction between the parties to the conflict.

The system includes modules: building and visualization of models based on CM, structural analysis of models, scenario modelling, visualization of results and generating reports. Scenario modelling is implemented in the following modes: (i) a mode of controlled development (direct task, "what will happen if ...?"); implying a targeted impact on one or more factors of the model; (ii) the mode of controls synthesis to achieve the set goals (inverse problem, "what should be done to ...? ").
4. Conclusion

The analytical, methodological and instrumental framework for the analysis and resolution of stakeholder interest conflict presented in the article expands the capabilities of information and analytical decision support systems in complex interdisciplinary stakeholder situations. The scenario approach to the analysis and study of various options for the development of a situation creates a formal basis for solving the problems of analyzing the conflict situation development under various predicted and/or hypothetical conditions of the situation. Early recognition of a conflict situation is based on a structural analysis of the situation model.

The direction of further research is associated with the development of a general technology to support decision-making in complex interdisciplinary situations, including support for continuous monitoring and analysis of the state of the situation, generation and testing of hypotheses of development mechanisms and control mechanisms of the situation, and the formation of scenarios for the situation development. The use of such technology significantly expands the analytical capabilities of experts whose activities are related to the preparation of decisions for decision-makers in such situations.

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