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Assessment of Command and Control organization structures based on confrontation analysis[1]

Topic 7

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Abstract: This article represents the recent advances in our program about the design and assessment of the C2 organization structure. In the past research, we assessed the hierarchical C2 organization structures with its reactivity and cooperation efficiency based on the untested hypothesis that a military organization with a good C2 structure can respond to tasks quickly and form the required effective cooperating group units. However, there are some problems that rationality, validity and completeness of evaluation index lack analytical basis. By deep analysis we have found that the high-strength confrontation is the essential element in C2 activities and it is the primary goal of C2 organizations to defeat the enemies efficiently in human recognition domain. Firstly, a new C2 activities descriptive model is presented which is explained in detail in another paper. Then, the method of C2 organization structures assessment and the measurement indexes is explained. Finally, our current work and the future working plan are presented in the conclusion.

1 Introduction

Since the last 80's, C2 organization structure design and evaluation have been a key point in the C2 research area. So far, a lot of research results about C2 organization structure design and evaluation have been obtained, and the primary research methods are as follows.

Initially, a series study on the C2 organization efficiency evaluation and design was done by A.H. Levis and other researchers based on information entropy. The theoretical framework of the theories and method is complete, and experiment design and analysis are practical. However, the modeling demands of the method are very strict and hard to satisfy [1]. And most importantly, it is unconfirmed that the unified describing the C2 decision-making process by uncertainty modeled with information entropy. In addition, the methods are difficult to be applied.

The U.S. military began the A2C2 project in 1993. The researchers proposed a three-phase organization design method and a robust and adaptive organization design method [2-4]. Kathleen M. Carley put forward PCANS model describing C2 organization and organization adaptive behavior model based on simulated annealing [5-7]. Both the PCANS model and the three-phase organization design method tried to generate sub-task sequences by task planning and then compute its corresponding C2 relationships. In fact, task planning in detail is very difficult, and in most occasions real time response is needed because of the uncertainty of the battle space. The methods are more suitable for a few simple local battles or low level, small scale and short period combats.

The research on edge organization began in 2004 [8-11]. Of which the results included C2 organizations description framework based on Mintzberg's structure in 5's, the computing model of C2 organization combat efficiency. The researcher applied the methods in the evaluation of six types of C2 organization including edge organizations and hierarchy organizations in different mission environments. However, there are some problems in the research. The theory and method of edge organization don't consider the high-strength cognitive confrontation in C2 activities that results in the complexity of decision-making activities, the high uncertainty of battle environment and the weakness of C2 organizations. These characteristics are the essential ones that distinguish C2 decision-making activities with the ones in other domains, such as general business decision.

Other than these large projects, some scholars applied complex science theory and methods to research on the C2 activities and organizations. Anne-Marie [12] applied CAS in C2 activities

and organization. They compared biological species to C2 organizations and systems, applied the adaptability and evolution mechanism of the former in the development of C2 organizations and systems, emphasized the influence of external environment on C2 organization, and paid attention to self-complexity. Bedsides, Hu [13] studied the combat complexity and its related problem using complexity science theories. The problem lies in that, although much progress has been made in complex science theories, there are still huge gap between the theories and the practical application [14].

In addition, from cognitive perspective some scholars researched on C2 activities and organization in network centric warfare. From 1999 to 2003, Perry studied the influence of information and knowledge on C2 organization combat effectiveness of different structures [15-17]. However, there are some problems in the research. Firstly, most of the mathematic expressions, the models and the hypotheses have not been effectively verified, which make its evaluation results not convicted. Secondly, every effectiveness computing model is close to specific scene and its applicability is strict, so the methods can't be applied widely. Thirdly, similar to Levis's research, information entropy was the basic modeling tool of C2 decision activities; the correctness and validity of decision activities evaluation are suspicious. M. P. Fewell [18, 19] pointed that the traditional OODA model cannot correctly describe the cognitive property of C2 activities. They proposed a description framework of C2 decision activities that divided the C2 activities into two basic types, adopted speed and quality as C2 activity effectiveness indexes and applied the method in a naval collaborative combat scenario. The problem of this research lied in the difficulty in quantitative describing and modeling the complicated cognitive activity and no consideration of the confrontation of C2 activity.

From the edge organization research we find that the structure design and the assessment of military organizations has no substantial difference with that of general business organizations. This is almost the common characteristic of the military organization research. W. Richard Scott, a part of the Edge Organization research team, pointed that "particularly in a military context, the lack of attention to issues of security is surprising", and questioned "Is the edge model consistent with a high security environment?" In his paper, he then pointed that the military is unique in its monopoly of violence [20].

We have the same questions about the research of C2 organization structures and we have even found that the models describing the C2 activities could be applied in the business domain. However, all of us know that these two type activities are completely different. We believe that high-strength confrontation is the element feature of the C2 decision-making activities and differs it from the activities in other domains. On the other hand, by the past research experience we have also found that the decision-making activities are high-level cognitive activities and C2 organizations are constitute with many cognitive individuals who communicate with each other, share in different level cognitive resources such as data, information, knowledge, and product higher-level cognitive results [21]. Thus, the assessment of C2 organization decision-making efficiency and the C2 organization structures requires that the researchers should take a deep insight into the C2 decision-making activities from cognitive perspective.

Thus, from cognitive perspective, we developed a new C2 decision-making model of which confrontation is one key factor affecting the decision-making efficiency. Moreover, a new method on C2 organization structures assessment is being developed.

This paper is organized as follows. Section 2 presents the description of the confrontation C2

decision-making model. Then, based on the model, the method of C2 organization structures assessment and the measurement indexes is explained in section 3. After that, we compare the method with the A2C2 and the Edge Organizations methods in section 4. Finally we give the conclusion including the existing problems, our current work and the future working plan in section 5.

2 A new C2 decision-making activity model

2.1 constitution of the new model

As is shown in Figure 1, the C2 activity model involves the cognitive and physical domains.

The cognitive domain consists of 4 levels: they are the data level, information level, knowledge level and strategy level from the bottom to the top, which are respectively the groupings of the following types of cognitive objects:

1. Data: the results of observing and measuring physical objects;
2. Information: the data which have been classified indexed and organized;
3. Knowledge: the information that has been understood and explained;
4. Strategy: the knowledge that can be effectively used to provide guidance in practice.

The above four types of cognitive objects are defined and classified from the cognitive perspective, but they do not exist for no reason. No matter it is data, information, knowledge or strategy, they are all related to physical entities. The functions of these entities include the storage, transfer, distribution and treatment of all kinds of cognitive objects. There are not any cognitive objects which can exist independent of physical entities. Furthermore, the change of physical entities, such as damage and alteration, will also result in the change of related cognitive objects.

The physical domain is constituted of all the related entities in the space of battlefield, including the battlefield environment and the staff, equipment, weaponry platform, and communications facilities of the enemy and our army. Through analysis, it can be found that the relationship between the objects in the cognitive domain and those in the physical domain is not that of one-for-one projection, but that of multiple projection. That's because one set of data may have been obtained from more than one sensor, and also may be stored in more than one physical entities. For the same reason, a physical object can store more than one set of data and knowledge at the same time. A commander is a typical example.

In Figure 1, the F domain indicates the projection between the cognitive domain and physical domain. The F domain re-classifies and organizes the entities in the physical domain P according to the cognitive levels. The entities in F domain and the cognitive objects in C domain correspond with each other, but the relationship between the entities in F domain and those in P domain is that of multiple correspondence.

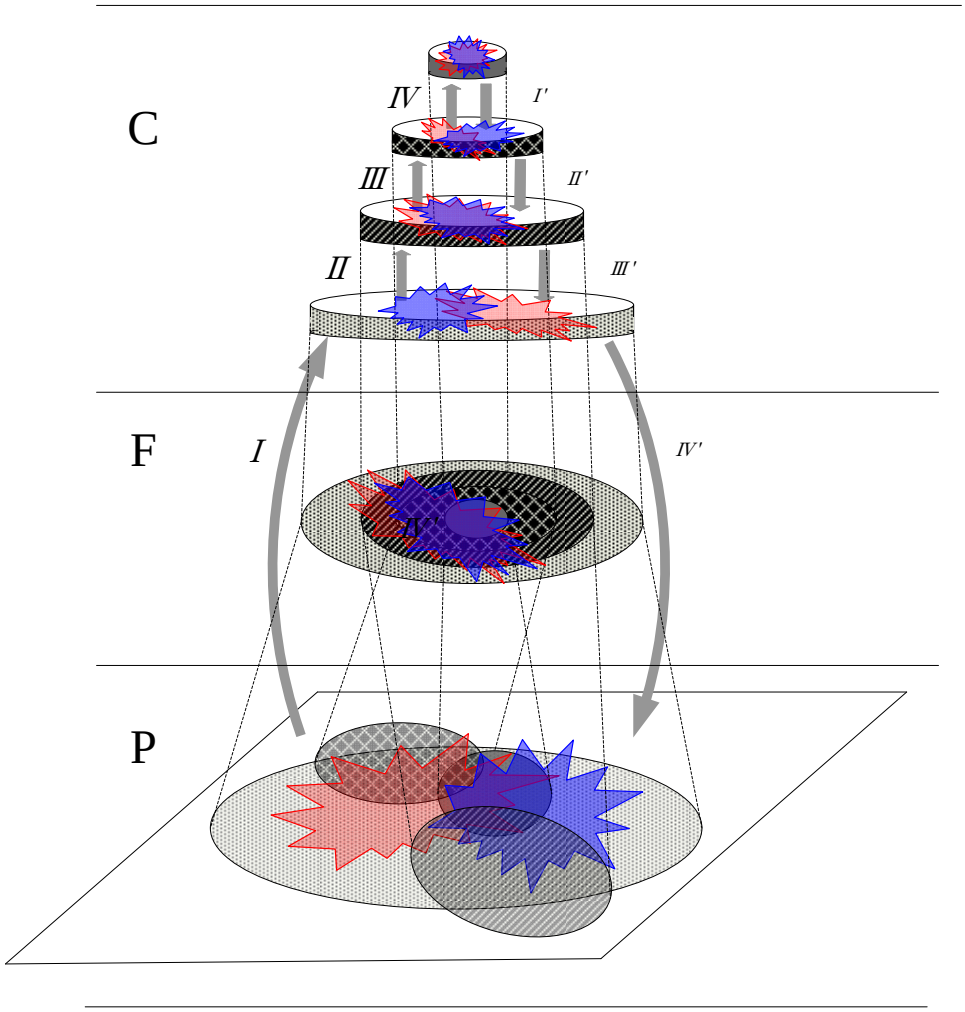

Figure 1 A C2 decision-making activities model with confrontation

2.2 One decision-making cycle

One decision-making cycle consists of 8 sub-processes which are divided into 2 phases. Sub-process $Ⅰ, Ⅱ, Ⅲ, Ⅳ$ belong to the first phase and sub-process $Ⅰ', Ⅱ', Ⅲ', Ⅳ'$ belong to the second phase.

- $Ⅰ$ (Observe). Being observed, measured and formatted, the physical entities are described in data such as the enemy staff, equipment, environment, etc. The possible description includes: time, space, measurement equipment, measurement number and that of the belief, etc.
- $Ⅱ$ (Manage). The data obtained in phase I are transformed, modified, selected, classified, indexed and stored as meaningful texts in order to be understood and applied more convenient. In the end the data will be stored according to some possible classifying standards such as space, time order, original, meaning, usefulness and other possible factors. Then the data can be called information.
- $Ⅲ$ (Understand). By cognitive individuals' comparing, searching, examining and other possible treatments, the static and dynamic relationships among the above information

can be found. The higher level information models are built to explain the information and their relationships.

- IV (Decide). It is high-level cognitive activities. The commanders make the strategies for the specific mission based on the above knowledge with the aids of the consultants and some possible computer systems [22].
- I' (Apply). The action plans and schemes are produced according to the decision in strategy level.
- II' (Explain). The plans and schemes are transformed into operational commands and other type information flow.
- III' (Operate)，The command and other type information are formatted as different type of data according to their usefulness that will be transmitted to the entities such as soldiers, platforms, equipments, etc.
- IV' (Act). The entities in the physical domain take actions after the data have arrived.

Such above decision-making 8 processes are continuous and happen at the same time.

2.3 Confrontation

As is shown in Figure 1, the confrontations between the Red Army and the Blue Army are described in red and blue waves that exit in each domain and all the levels. The confrontations in physical domain are the mappings of the cognition confrontations in cognitional domain. Both of the two armies try their best to realize the cognitive superiority and get the charge of cognition control.

A simple example is used to explain the effect that the confrontations have on the cognition superiorities. In the battle with the Blue Army, the Red Army has found the place of the commander by using satellite technology to trace his mobile phone signals. Then the Red Army emits a missile and hit the command office. The commander is dead. This could be explained by the model as follows. The entities of the Blue Army in the P domain have been destroyed by the Red Army. What this event is projected into the F and C domain is that the relevant entities in F domain and the cognitive resources in C domain are also destroyed greatly. Moreover, the key cognitive entities and the important processes are ruined. All of these reasons, the cognitive capabilities of the Blue Army have been destroyed greatly. This model can answer the question directly and clearly -why the confrontation damage with small number persons lost causes such a great strike to the Blue Army. If the Blue Army has no candidate command office and put it into use at once, it will be defeated. This simple example verifies that including fire attacking and information disguising, the confrontations in battle space are all the means to realize cognitive superiority and master the cognitive control in the end. This conclusion can also be strengthen by citing the sentence of Sun Tzu “The best warfare is the one that can defeat the enemy without any operation” [23].

2.4 Analysis

Figure 2 is used to analyze the effect that the confrontation have on the cognitive capabilities and the final decision by describing the cognitive process in the first phase of a decision-making

cycle.

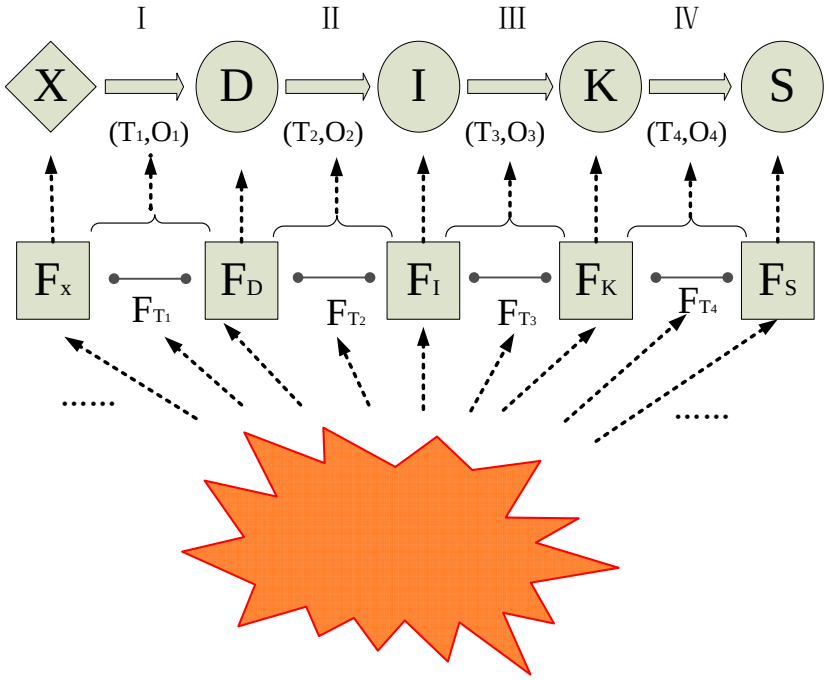

Figure 2 Cognitive process of the confrontation C2 decision model

As showed in figure 2, phase I, II, III, IV correspond with the ones in figure 1. X As the cognitive ontology of the cognitive objects. D, I, K, S are used to represent the cognitive resources and results in data, information, knowledge and strategy level. F_D, F_I, F_K, F_S are the relevant entities in physical domain. $T_i (i = 1,2,3,4)$ are the processing operations that don't change the meaning of the cognitive resources or results such as transmitting. $O_i (i = 1,2,3,4)$ are the processing operations of which the goal is to produce new or higher-level cognitive resources. $F_{Ti} (i = 1,2,3,4)$ is the relevant entities that undertake the operations $T_i (i = 1,2,3,4)$.

So, the following can be obtained:

$$D = (T_1, O_1)(X), I = (T_2, O_2)(D), K = (T_3, O_3)(I), S = (T_{4,} O_4)(K) = Y \quad (1)$$

For the confrontation exists, $X \to X'$, and :

$$D' = (T_1', O_1')(X'), I' = (T_2', O_2')(D'), K' = (T_3', O_3')(I'), S' = (T_{4,}' O_4')(K') = Y' \quad (2)$$

From figure 2 and the above formulas we conclude that the confrontation in P domain affect the cognitive activities in different levels of the processes and may cause the output Y' change greatly. For the Red Army, the goal of the C2 organization is try to make its own cognitive result $Y_R' \to Y_R$ and make the enemies' cognitive result $Y_B' \to Y_{RE}$. Here, Y_{RE} is the result that the

Red Army wish the Blue Army to produce.

3 A method to assess C2 organization structures

3.1 Explanation

It can be found in Figure 1 that the nature of C2 decision-making activities is that C2 organizations try to protect their own cognitive resources and the relevant cognitive processes from destroying by taking confrontation measures, and meanwhile, make the enemy cognitive result change as they wish. This can be understood as contending for the decision-making superiority which is the goal of C2 organization. A good or satisfying C2 organization is an organization that can still finish its cognitive task and master the cognitive superiority when its enemy take all kinds of measures to weaken it.

The internal structure of C2 organizations can be understand as cognitive individual team. These individual undertake different level cognitive sub-tasks, share relevant cognitive resources and communicate with each other according to the rules of the organizations. Finally, the cognitive results on the statistic level are presented.

The distribution state of these cognitive individuals, their communication methods and the relevant working process constitute the condition of C2 organization in cognitive domain which We call as cognitive domain structures of C2 organizations. It can be easily accepted that the cognitive domain structures have directly effect on the decision making activities of C2 organizations. A good cognitive domain structure means that the cognitive individuals are located in the right place according to their capabilities, the cognitive resources are shared effectively, the individuals communicate with each other and result good cognitive results quickly, etc.

The method of C2 organization structures assessment is as follows:

- **Step1**. The specific mission or task will be transformed into the cognitive task according to four different cognitive levels-data, information, knowledge and statistic.
- **Step2**. The parts of the C2 organization that undertake the cognitive tasks will be analyzed to find its cognitive domain structure according to some rules.
- **Step3**. The cognitive decision-making process will be modeled in a decision-making cycle.
- **Step4**. Based on the specific mission, the possible battle confrontation will be transformed into the loss of the relevant cognitive individuals and resources.
- **Step5**. The battle confrontations will be classified into different levels according to the extent of that the cognitive organization has been damaged.
- **Step6**. The measurement indexes of the C2 organization structures will be calculated with different level confrontations.
- **Step7**. The assessment of the C2 organization structures will be concluded by analyzing the measurement indexes.

3.2 Indexes

The goals of C2 organizations are that, finishing the cognitive processes as quickly and well as possible, and meanwhile, hindering the cognitive ones of the enemies by all kinds of means to make the enemies act on their will in the end. So, we adopt cognitive reactivity time, cognitive quality and cognitive anti-attack ability as the index to assess the cognitive capabilities of C2 organizations. The assessment method consists of the following steps:

(1) To develop cognitive focus questions based on the specific mission

A cognitive focus question is the question of which the answer is very important for the army to perform the task. For example, it may be the force deployment of the enemy, the action plan of it or other important cognitive resources. The focus questions are the key cognitive tasks of the both sides which consist of an attacking side and a defending one. The attacking side tries to collect the relevant information and find the correct answer quickly, and meanwhile, the defending side tries to hinder the enemy's collecting and destroy the cognitive process by all kinds of possible means.

(2) To develop the corresponding cognitive processes graphs of the cognitive focus questions;

Both the two sides have their own cognitive questions and the corresponding cognitive processes which are performed by the relevant C2 organizations. The graphs consist of cognitive nodes and links which can be obtained by mapping the physical organizations into the virtual cognitive entities according to some rules. So, the graphs can also be understood as the cognitive organization structures graphs.

(3) To calculate the indexes based on the cognitive graphs

- Cognitive reactivity time $T(F,O)$

This index is used to show the cognitive speed of C2 organizations. A smaller value indicates a faster speed and a higher-level cognitive organization. $T(F,O)$ is the decision-making cycle time needed by the organization with a structure O to solve the focus question F. The value of $T(F,O)$ can be obtained by calculating the total time spent in the relevant cognitive chains. As the basic decision-making cycle time of the armies, $T(F,O)$ is a very important index for the efficiency of C2 organizations' cognitive processes. Suppose that $T_R(F,O) \prec T_B(F,O)$, it means that the Red army can finish a decision-making cycle quickly and take a new action before the Blue army responses on the old situation. Thus, the cognitive process of the Blue army will be interrupted and thus the Blue army can't take suitable actions timely.

- Cognitive quality $Q(F,O)$

This index is to indicate the extent that the C2 organization with a structure O can solve the focus question F. The calculating of the index $Q(F,O)$ is difficult. The relevant factors

include the topology of the cognitive processes graphs, the corresponding cognitive abilities of the nodes and links, etc.

- cognitive anti-attack ability $U(F,O)$

This index indicate the ability that the C2 organization with a structure O anti the enemy' hindering actions in the cognitive process about the focus question F. It can also be understood as the ability that the other side takes hindering actions:

$$U(F,O) = 1 - E \bullet P \tag{1}$$

Here, E is the extent that the normal cognitive function be destroyed and P is the probability of the destroy events happened on the cognitive chains such as information attacking.

- Cognitive ability $C(F,O)$:

$$C(F,O) = k \cdot \frac{1}{T} \cdot Q \cdot U \tag{2}$$

This index indicates that the cognitive ability level of the C2 organization with a structure O deals with the focus question F. Here, k is some coefficient. For the same C2 organization, different structures correspond to different values of $C(F,O)$ and a better structure can be selected by comparing the values.

Furtherly, cognitive superiorities can be assessed by calculating the difference value of the Cognitive ability $C(F,O)$ of the two sides:

$$\Gamma_{ij} = C_i - C_j \tag{3}$$

It is noted that the above indexes are not unchanged. With the battle goes on, the focus questions and the relevant cognitive structures will change. Thus, the values of the indexes should be updated timely according to the corresponding battle development.

4 Comparing the methods

One of the two basic features of this idea is that it takes high efficiency cognitive activities as the organizations' goal which is the basis of the assessment of the C2 organization structures. The other essential characteristic of the idea is that the high-strength confrontation in cognitive domain is understood as the fundamental element of the C2 activities and thus is modeled directly in the assessment of the efficiency of C2 organization structures. Different from this method, the confrontation factor is not taken into account in other methods that are developed in A2C2 and EO programs. In these programs, the researchers dealt with the confrontation indirectly by using the relevant probability theories in modeling the high-dynamic battle environment. That is, we can say, the confrontation is neglected or be understood as some conditional variable. This modeling idea may have two bad effects. On the one hand, because of being simplified incorrectly, the probability of the "battle environment variable" is not true; on the other hand, the research couldn't be advanced as the key elements and the mechanism are neglected.

The idea explained in this paper and the methods in A2C2 program correspond respectively

to two means to find a suitable organization when a task is provided. The first means is to select a capable team that can satisfy the specific requests that is obtained by researching on the task but not planning. As to how to perform it, it is the duty of the capable team. The second means is that, by planning accurately the task can be divided into sub-tasks, and then based on that the resources and persons are allocated, finally the organization can be produced after the relationship between the persons is worked out. We think that, the second means is more suitable for the organization design in industry production, business domain activities and etc. Different from the activities in war, the number of the factors in these kinds of activities is small and the value range of the factors is also small. It is obvious that the organization structures are fragile which are obtained by action planning.

As to EO program, it adopted the general organization theory which is widely used in business domain and neglected the key role of the cognitive confrontation in C2 activities. Its research results on the matching laws between the C2 organizations and the mission environments are explained with the terminology of Management Science, though the information and knowledge flows are modeled. According to the idea in this paper, we can explain intuitively why the edge organization can't match with all kinds of the mission environments in information age. Though the edge organizations can response more quickly than the traditional pyramid organizations, their scores in other two indexes, cognitive quality and cognitive anti-attack ability, may not higher than the pyramid ones. The edge organizations have less information collecting branches. On the one hand, the cognitive quality has no superiority than the pyramid ones that have more branches. On the other hand, once the fewer branches are attacked, the cognitive chains are destroyed more heavily than that of the pyramid ones. We believe that, the cognitive confrontation is the fundamental factor that should be took into account in the research about the matching between missions and C2 organizations.

5 conclusion

This paper analyses C2 decision activities, proposes a new C2 decision activity model based on cognitive confrontation, and a evaluation method including some indexes. But because of lack of deep understanding of C2 cognitive activities, the computing method of evaluation index in this paper are simple and crude. The future research work is to improve the computing method of the indexes to make it better reflect C2 organization cognitive level, and design relevant experiments about cognitive confrontation activities in order to verify the assessment method.

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