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The conceptual model of agile command and control system

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Authors

DUANMU Zhu-yun

MAO Xiao-bin

Wang Heng

Point of Contact

DUANMU Zhu-yun

Name of Organization

Science and technology on information systems engineering laboratory,

Nanjing, Jiangsu, 210007, P.R. China

China Justice Big Data Institute,

Beijing, 100083, P.R. China

Address

Nanjing, Jiangsu, 210007, P.R. China

Email

fairydm@qq.com

The conceptual model of agile command and control system

DUANMU Zhu-yun[1], MAO Xiao-bin[1], Wang Heng[2]

[1]Science and technology on information systems engineering laboratory,

Nanjing, Jiangsu, 210007, P.R. China

[2]China Justice Big Data Institute,

Beijing, 100083, P.R. China

Abstract

To adapt the changes from the battlefield environment and the self-status, a command and control (C2) system has to be agile. Modeling agile C2 system is still an open problem in the field of military command and control. In this paper, the conceptual model of agile C2 system is given by describing dynamics of changes, capability characters, and operation evolution process. Then, based on the self-adaptive theory, the agile operating mechanism to cope with these changes is proposed.

1 Introduction

Agility research begins with agile manufacturing, which focuses on dynamic integration and cooperation among companies in order to deal with rapid changes and unpredictable market demands. It is a brand-new manufacturing organization model that improves the competitiveness of companies (groups). Applying to the military field, agility has become the most important feature of the transition force under network center operational environment[1-3]. Agility is the ability to successfully effect, cope with, and/or exploit changes in circumstances, which has six components, including responsiveness, versatility, flexibility, resilience, adaptability, innovativeness[4].

In the 21st century, the military power led by the US Army have accelerated the transformation of C2 systems, and have evolved from chimney-style, customized C2 systems to focusing capabilities C2 systems, such as Global Combat Support System-Joint(GCCS-J), Net-Enabled Command Capability (NECC) [1] . In order to achieve the agile demand, the construction of the C2 system will no longer be confined within the system in the future grid network environment. It will span the boundaries of the traditional system, and system resources belonging to different military organizations in different geographic locations will be able to provide external capabilities through grid network. Then it is possible to build C2 system according to different military missions. However, how to build the mission C2 system by coordinating system resources to respond to changes, will become key issues to be

solved in the construction of agile C2 systems[5]. Aiming at this issue, a preliminary study of the concept model of agile C2 system has been carried out, with a view to provide theory and method support for the construction of agile C2 system.

2 Basic concepts

Based on the theory of combat agility and C2 agility, the concept of agility is defined from task level, organization level, and system level, as shown in Figure 1. The combat agility at the task level requires the ability to respond to sudden and uncertain joint missions quickly and effectively. The C2 agility at the organizational level requires the ability to select the best task force and establish the C2 organization quickly. The system agility requires the ability to organize various system resources quickly and optimally. These distributed system resources which belong to different organizations, can form system capabilities that meet the requirements of tasks by performing interactions and collaborations according to certain business processes. It responds to internal and external changes and forms an agile C2 system, namely agile C2 system.

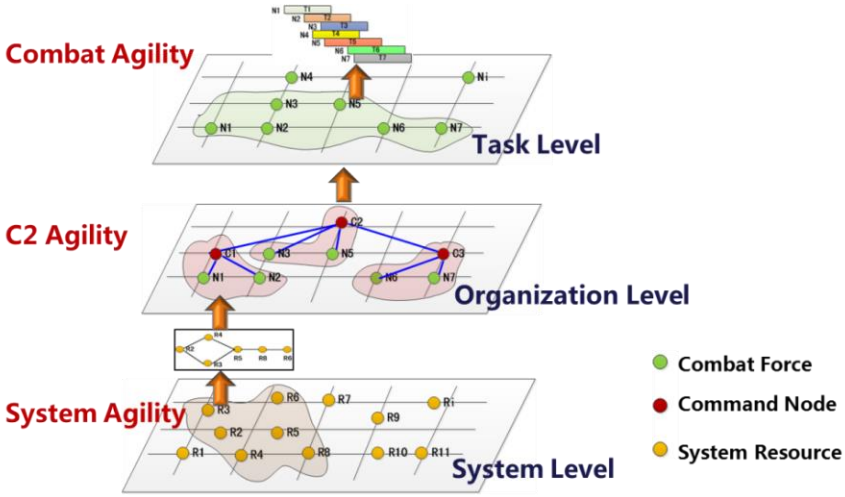

Figure 1 Agility Hierarchy Concept

The construction and operation of the agile C2 system focus on the dynamic cooperation between the selected system resources, in order to improve the flexibility of the C2 system. The core characters of agile C2 system are operations mission driven and the system resource cooperative structure adjusting. Operations mission driven is the input of the various operations mission, through the reasonable choice of the grid network distribution system resources, and optimize the structure and relationship between resources to meet the operational requirements of the stability of the system. Cooperative structure adjustment is to maintain good overall effectiveness in the face of the fierce changes in the internal state of the operations mission and system resources.

3 The conceptual model of agile C2 system

Since change is an essential prerequisite for agility, it is the dynamics cause of agility. The conceptual model study for the agile C2 system will first conceptually model the cause of agile C2 system, to answer which changes C2 system should respond. Then, based on input of cause, capabilities of the agile C2 system are analyzed and quantitative descripted, to answer what abilities C2 system should require. Finally, based on input of cause, aimed at the agility of C2 system, the system state transfer function is established, and a conceptual model of the evolutionary process of the agile C2 system is constructed, to answer how C2 system should respond.

3.1 The conceptual model of cause

Based on C2 process model (OODA loop model), the changes that C2 system need to manage is analyzed in each phase. These changes comes from the external environment , the internal state of the C2 system and the constant interaction between the two, as shown in Figure 2.

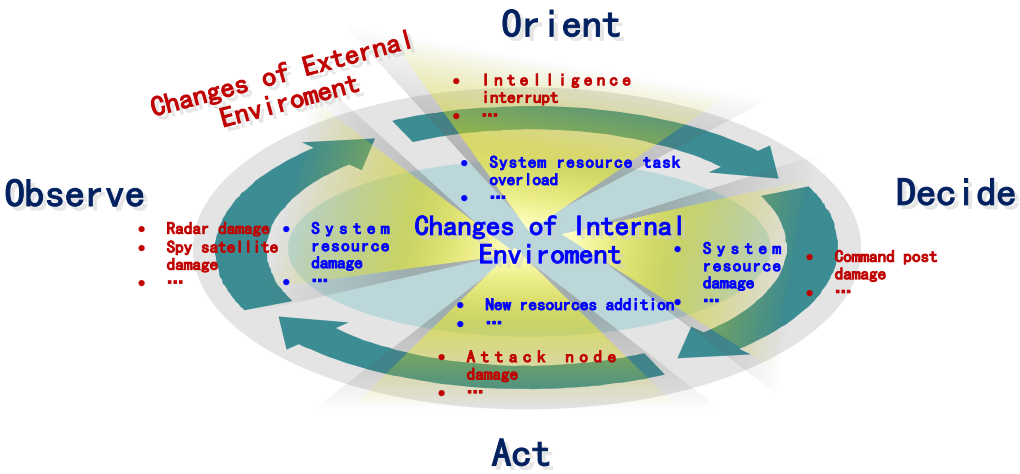

Figure 2 illustrates the cause of the agile C2 system

The cause conceptual model of agile C2 system can be expressed as follows:

$$\Omega = \Omega_{internal} \cup \Omega_{external} \cup \Omega_{people} = \{\omega_{11}, \omega_{12}, \cdots\} \cup \{\omega_{21}, \omega_{22}, \cdots\} \cup \{\omega_{31}, \omega_{32}, \cdots\}$$

Among them, $\Omega_{internal}$ represents the change set of system resources status, including system resource task overload, resource damage, new resource addition, information processing capacity and type change in the system, etc. $\Omega_{external}$ represents the change set of the battlefield enviroment, including the change of combat type and scale, C2 objects damage(such as command post damage, attack node damage), and information source changes(such as radar damage, spy satellite damage). Ω_{people} represents the change set of commander's behavior , including command patterns, command authorization, user preferences, etc.

3.2 Capability character model

Agility is the ability to cope successfully. And agile C2 system should maintain an acceptable level of effectiveness and efficiency in the face of changes in circumstance that result in a loss of equilibrium. This paper takes the agile cause as input and aims to maintain stable output of system performance. Based on Dr. David.S.Alberts' work on agility, this paper summarized capability character of agile C2 system, including responsiveness, versatility, flexibility, resilience, adaptability, innovativeness.

(1) Responsiveness denoted by A_t: refers to the ability to respond to changes in time, that is the recovery efficiency for C2 system responds to changes. It is defined as :

$$A_t = \Delta T = T_f - T_0$$

where T_0 is the moment of change; T_f is the moment of system recovery.

(2) Versatility denoted by A_v: refers to the ability to use various measures to achieve an acceptable level of system performance or effectiveness, facing significant changes of mission and task. It is defined as:

$$A_v = Dim(C)$$

where C is evolutionary strategy space; $Dim(C)$ is the dimension measurement function for C.

(3) Flexibility denoted by A_m: refers to the ability to quickly find a candidate solution to achieve an acceptable level of system performance or effectiveness, when system cannot be implemented, does not work , or does not well enough in a particular situation. It is defined as :

$$A_m = \frac{\|R\|}{n(M)} or \frac{\|R\|}{n(\Psi)}, \quad R \in U_R$$

where R is task space; $\|R\|$ is the modulus of the vector; U_R is the range of R; $n(M)$ and $n(\Psi)$ is the baseline for the external and internal task states.

(4) Resilience denoted by A_c: refers to the ability to recover or adjust, when system is destructed, interrupted, or degraded, including repair, replace, repair, patch, or otherwise reconstitute lost capability or performance. It is defined as:

$$A_c = \frac{\Delta Y}{|Y_0|} = \frac{|Y_f - Y_0|}{|Y_0|}$$

where Y_0 is the performance before the system changes; Y_f is the performance after the system recovery.

(5) Adaptability denoted by A_p: refers to the ability to adapt to external and internal changes by adjusting internal structures and workflows. It is defined as:

$$A_p = Dim(R_a)$$

where R_a is task subspace that system could successfully cope by changing internal structures and workflows. $Dim(R_a)$ is the dimension measurement function for R_a.

(6) Innovativeness denoted by A_s: refers to the system's ability to learn historical data and identify new evolutionary strategies to deal with changes actively. It is defined as:

$$A_s = Dim(R_n)$$

where R_n is task subspace that system could successfully cope by new evolutionary strategies learned from historical data. $Dim(R_n)$ is the dimension measurement function for R_n.

3.3 Operation evolution process

The Operation evolution process of agile C2 system is the process of maintaining and updating the system according to the changes of requirements and environment, and has the characteristics of feedback response. From the system and cybernetic point of view, the agile C2 system can be initially formalized, including the system's input and output, state variables, control variables and other elements, as shown in Figure 3.

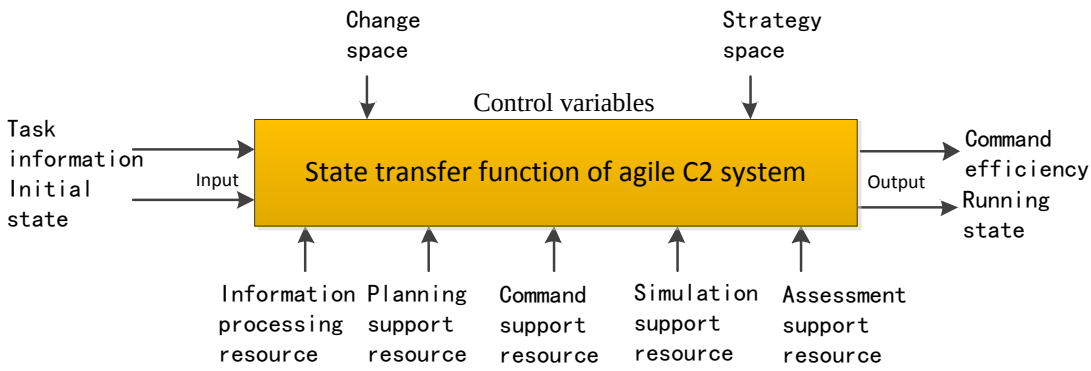

Figure 3 Formal representation of agile C2 system

According to the input-output relationship of the agile C2 system, the state transfer function can be expressed as follows:

$$X(t) = F(X_0, M, \Omega, C, t)$$

$$Y(t) = G(X, I, t) = G((F(X_0, M, \Omega, C, t)), I, t)$$

Among them, $X = [x_1, x_2, \cdots, x_n]^T$ is the status of the agile C2 system; T is transposition. X_0 is the initial designed status. Y is the performance of the agile C2 system , based on the current status and intelligence data. M is the current C2 task. I represents intelligence data which agile C2 system depends on. $\Omega = \Omega_{internal} \cup \Omega_{external} \cup \Omega_{people}$ represents the cause of agile C2 system. $C = [c_1, c_2, \cdots, c_p]^T$ represents the response strategy of the agile C2 system.

4 Operating mechanism of agile C2 system

The agile C2 system is a dynamic and evolvable system. Its operation process is the process of the system maintaining and updating responding to the changes of the requirements and the environment. Based on the adaptive evolution process model for complex system, operating mechanism of agile C2 system is analyzed, which includes perception, decision-making and execution, as shown in Figure 4.

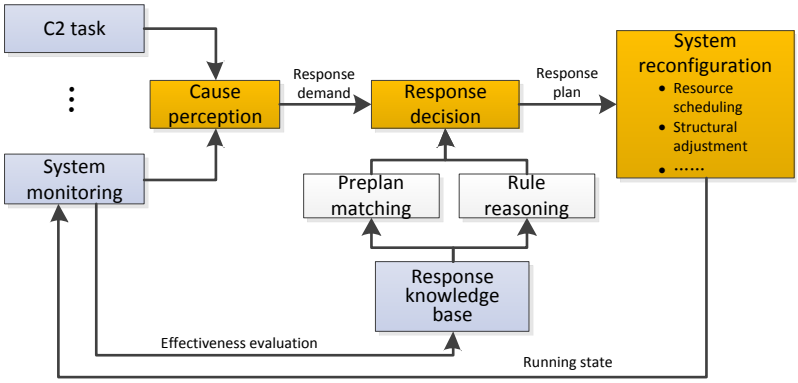

Figure 4 Operating mechanism of agile C2 system

Cause perception is the premise of C2 system to achieve agility. It identifies the cause from information sources such as system monitoring, C2 tasks, and the external environment. Response decision-making,which is called the system's agile brain, pre-plan matching and rule reasoning based on the response knowledge. Reconfiguration execution, which is called the system's agile behavior, includes resource scheduling and structural adjustment which based on the response scheme.

5 Conclusion

As a brand-new concept in C2 system development process, the research for agile C2 system is only carried out from a preliminary and exploratory way in this paper. The conceptual model and operating mechanism of agile C2 system is proposed initially. However, further studies are needed on how to quickly identify cause, how to optimize operational mechanisms to achieve agility, and how to dynamically assess agile capabilities.

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