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The Research of C^{4}ISR System Design and Modeling Method Based on Model

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In order to solve the problem of low degree of digital design of C^{4}ISR system, a model-based system design and simulation method is proposed to change the existing system design mode based on document. The design elements of C4ISR system are divided into basic resource class, common service class and application system class in this paper, in which, the classification system of the system design elements is established and the design elements are mainly characterized by basic resources and common services; besides, the application system is extracted. The parameterization model of the system design elements is established from the perspective of structure, function and behavior. The parameterization model of system design elements is formally described by using block definition diagram, activity diagram and timing diagram of SysML. The parametric model of the system design elements can be directly mapped to the system simulation model, and the digital prototyping of C^{4}ISR system is built by the model conversion technology so as to support the demand of the whole life cycle, the overall design, the function of sub-system design validation, iterative adjustment and optimization.

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1.Introduction

With the development of information technology, the army C^{4}ISR system has entered a new stage of network and service development [1-2]. On the one hand, the network and services can greatly improve the flexibility of the system, enable the system to share network resources and generate new capabilities in order to dynamically adapt themselves to the battlefield and mission changes; on the other hand, the network and services have also greatly increased the scale of system, functions, types of resources and a variety of interactive behavior. In addition, in order to support the combat mission, combat mode has changed, from the traditional single weapon system/equipment combat into a multi-armed arms of the joint operation mode. The components of the system are different from the existing C^{4}ISR system. The components of C^{4}ISR system are networked and served. The components of C^{4}ISR system are finer, and the components such as computing storage facilities, common services and information application systems, etc. are composed. At present, the design of C^{4}ISR system is mainly based on the design pattern of the document. Based on the system design and analysis method, the system is developed through manual conversion method. The digital design level is low and lacking the quantitative system design model and the guidance to follow-up the system development.

In order to solve this problem, a model-based system design method is proposed in this paper, the classification system of C^{4}ISR system design elements is established with the domain features of various design elements as extracted, the domain parameterization model of design elements as established while using the Graph, activity diagram, timing diagram of SysML to describe the system design element parameterization model.

2.Related Research

Considering the design and modeling problem for the construction of weapon equipment system and C^{4}ISR system, a model-based system engineering design method (MBSE) is proposed by the American Society of Systems Engineering (INCOSE). As domestic researches on SysML in the field of military operations command information system started lately, it cannot yet form from the demand for design to system development integration of a set of solutions and tools products[3-4]. National Defense University of Science and Technology applies SysML method to the design and modeling of the C4ISR system[5-7], such as the composition, interface and communication, function, state transition and system event tracking of C^{4}ISR system, and the system based on the block definition Composition description, system interface and communication description based on internal block diagram and system function description based on activity diagram, etc.. In addition, in order to solve the problem of accuracy and completeness of the semantic expression in C^{4}ISR system modeling, a method of C^{4}ISR system analysis and design model based on SysML is proposed. The design of C^{4}ISR system is further explored and explored by SysML[8-10]. Quantitative analysis of the advantages, but it failed to take the system of quantitative performance indicators and action behavior into the system model, lacked consideration of the system design model in respect of how to switch to the system simulation model.

3.Analysis of C^{4}ISR System Design Elements

The elements of the existing C[4]ISR system design are classified by system-subsystem-subsystem-module rule, and the various elements are interacted and integrated according to the predetermined interface. The technology system of network and service system follows the network information system architecture with more types of system design elements, wider range, more granular, involving computing, network, storage and other physical infrastructure resources, running on the basis of resources on the calculation storage services, software services, information services and application systems.

Considering the above characteristics, this study refers to the network architecture of the three-tier network information system,reference DoDAF system view design method in combination of the composition of the analysis system module and the same function, The modules are clustered to obtain the classification system of the system design elements, including basic resources, common services and application systems, as shown below:

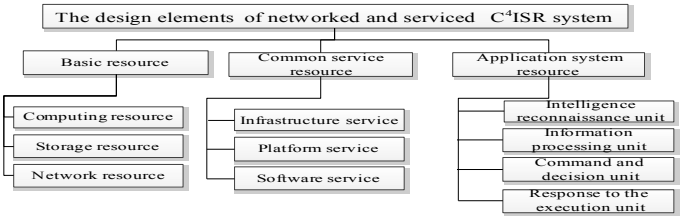

Figure 1: Design Elements of The Network and Service C[4]ISR System

Wherein, the basic resources refer to the hardware resources of system, including computing, storage and network resources.

Common service resources are the key elements different from the traditional C[4]ISR system in terms of infrastructure services, platform services, software services and other resources so as to provide resource management, information services, systems integration services and other common functions.

The application system resources refer to the application system of operational activities related to intelligence, command and control.

4.Model of C[4]ISR System Design Element

4.1Modeling of Basic Resources

The basic resources refer to the physical hardware resources demanded by C[4]ISR system to run and provide the basic support for system interconnection and resource management. This study divides the basic resources into resources such as calculation, storage and communication network resources. As far as the resources are concerned, their characteristics are extracted from general attributes and special attributes as the parameters of resource design model. On this basis, the basic resource characteristics are described by SysML modeling method.

4.1.1 General attribute of the resources

Generic attributes describe the common attributes of resources, such as calculation, storage and network, which are specific to the resource category, name, logo, geographical location, scope of authority, affiliation, density and available status, etc..

4.1.2 Special attributes of resources

(1) Specific attributes of calculating resources

Computing resources is responsible for the system specific calculation tasks and the implementation of computing instructions to mainly provide the form of virtualization after the

computer/container. The essential characteristics of the computing resources will be extracted from the aspects of identification of hardware, performance indicators, etc.The multiple attribute group method is used to describe as follows:

$$ComRes::=<ResChar,ResPerfor> \tag{4.1}$$

Wherein, $ResChar$ refers to the identification characteristic of resource, mainly including the processor model/version, the display model/version/ resolution. $ResPerfor$ refers to the performance characteristics of resources.

(2) Essential characteristic of storage resources

The storage resources are responsible for storing data and information, providing the data used for calculation and the virtual storage blocks in the form of unified distribution. The essential attributes of storage resources include storage capacity, access speed, usage protocol, snapshot ID and storage cycle, etc.

(3) Essential characteristic of communication network resources

The communication network resources provide the communication channel of physical node of C^{4}ISR system, which mainly provides the form of physical network card, virtual network card, virtual bridge, tunnel, network port, etc. The characteristic of resources is extracted from network node, communication link and network protocol.

4.2 Modeling of application system resource

The modeling idea is to utilize the system structure design method based on the block definition graph. The performance parameters, the relationship between the parameters and the operation of the model are defined by attribute ,operation , flow port aspects. Then the system structure design models of information processing, battlefield situation generation, command decision and other systems are established.

Among them, the attribute describe the membership level of operation function system and the system performance parameters; the operation describes the operation about function system consistent with the activity in the SysML activity diagram; the flow port describes the input/output interface between the system components module consistent with input and output of SysML activity gram. Afterwards, the field feature extraction and modeling are carried out for the intelligence reconnaissance unit, the intelligence processing unit, the command decision unit and the response execution unit respectively.

(1) Domain characteristics on intelligence reconnaissance unit

The unit represents intelligence reconnaissance, surveillance and detection system, including all the units that provide operational space perception. The function of intelligence reconnaissance unit is to obtain all kinds of information about the enemy and the enemy in the combat space. The characteristics are built, as shown below:

$$QbR::=Value,Oper,Flow> \tag{4.2}$$

$Value$ include the obtained intelligence species, detection radius, the maximum search target, the maximum tracking target number. $Oper$ includeing the intelligence reconnaissance, intelligence data processing, intelligence data reporting. $Flow$ coveres the intelligence reconnaissance mission/ directive, original information.

(2) Domain characteristics on information processing unit

The unit brings together all kinds of reconnaissance intelligence data of battlefield, intelligence solved data, intelligence fusion processed, intelligence analysis and service,

generating joint intelligence product, providing intelligence guarantee for the joint situation consciousness and the joint command decision. The established characteristics are shown below:

$$QbP::=Value,Oper,Flow> \tag{4.3}$$

$Value$ covers the type of information processing, the number of batches of target processing, density, precision and timeliness,etc. $Oper$ covers the intelligence data aggregation, integrated information integration, intelligence on-demand distribution. $Flow$ covers combined situation generation system and joint combat planning support.

(3) Domain characteristics on command and decision unit

The unit is collectively referred to as the command and control system, and is responsible for receiving intelligence information reported by intelligence processing unit, making the threat judgment, developing the combat plan, and cooperating with the command unit and the response unit command and allegations.The domain characteristics are established, as shown.

$$C2::=Value,Oper,Flow> \tag{4.4}$$

$Value$ include system membership level, combat planning process time, the planned plan preparation time and the program report generation time. $Oper$ includes combat mission analysis, joint goal analysis, the task force group, the plan plan factions, command order generation and so on. $Flow$ covering task lists, situation information, joint operations programs, joint operations plans, command orders and so on.

(4) The domain characteristics on response to the execution unit

The unit represents entity unit that can be soft and hard hit, and combat command of receiving decision control unit attacks and disturbs target, covering land, sea, air. The establishment of the weapons platform unit properties, operations, flow port, as shown below:

$$Act::=Value,Oper,Flow> \tag{4.5}$$

$Value$ include action control instruction generation, action control instruction release, fire strikes, status reporting. $Oper$ covers action control instruction generation, combat execution status. $Flow$ includes action control instruction, operation status and operation effect.

Comprehensive analysis， the application system parameterization model is established based on the definition of SysML block definition, such as shown below：

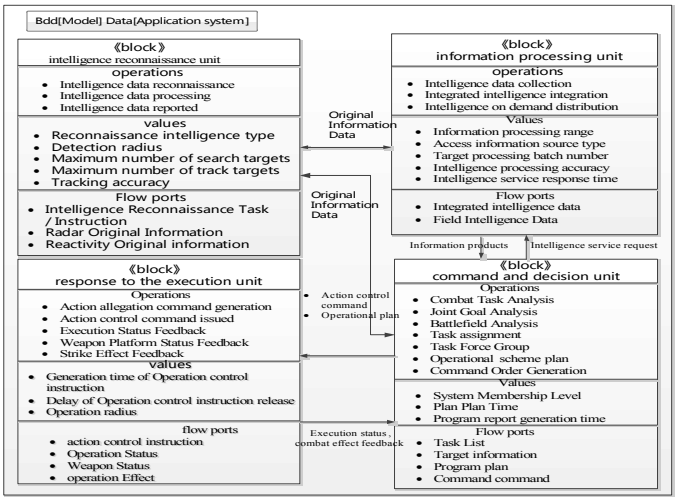

Figure 2: Design model on application system based on block definition graph

5.Simulation Result

5.1 Simulation Experiment Condition

Taking a regional joint air defense system as an example, the design and modeling of the regional joint air defense system based on SysML is carried out, including the modeling of the system components and the information interaction between the units.

(1)Intelligence reconnaissance unit (indicated by O)

Each intelligence reconnaissance unit (radar unit) is responsible for detecting and monitoring the air targets in different areas of responsibility to obtain real-time availability data and provide original intelligence data for intelligence processing units

(2) Information processing unit (indicated by P)

It is responsible for the integration of the original intelligence data processing, the fusion processing results reported to the network center for further integration.

(3) Decision control unit (indicated by D)

The unit mainly includes battle direction command post and air command post.

(4) Response to execution unit (indicated by A)

This unit mainly includes combat aircraft, responsible for the implementation of different directions within the region to invade the target air interception task.

5.2 Simulation Experiment Result

Based on the above system design and modeling method based on SysML proposed in this paper, the design model of regional air defense system is established, as shown in the following figure.

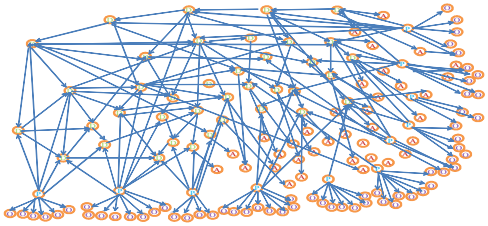

Figure 3: Structure Model for Regional Joint Air Defense System

The design model is established of the above system elements by using block definition diagram (BDD)of SysML, taking information processing unit for example, the design model of this unit is shown as following:

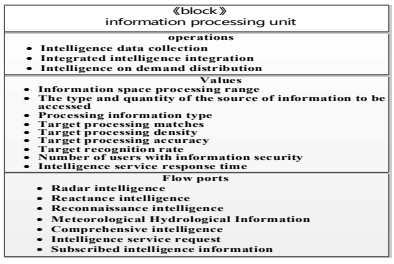

Figure 4: Design Model of the Information Processing Unit

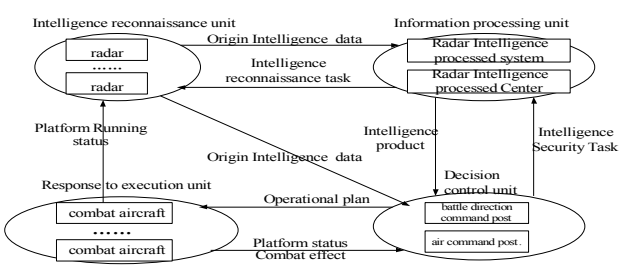

Figure 5 : Design Model based on Traditional DoDAF Architecture Design Method

In order to validate the effectiveness of the proposed method, the method proposed in this paper is compared with the traditional design method based on DoDAF system architecture. The following figure shows the system component unit and its information interaction model based on DoDAF system view.

From the above experimental results, the proposed method in this paper can fully establish the models about the properties, operation and interface of system, and can quantitatively analyze the system design results. The traditional DoDAF architecture design method is difficult to describe the specific properties of system unit, the design of coarse particle size and lack of quantitative analysis of the system unit function so as to verify the validity and advancement of the proposed method.

6.Conclusion

The running mechanism of system engineering based on model is analyzed in this paper by considering the design and modeling problem about the networked and service C4ISR system and utilizing the system modeling language. The designing model of basic resources, information services and application systems and other aspects of C4ISR system components is built through model including the block definition chart, activity diagram and timing diagram. In the subsequent study, the conversion mapping technology from the system design model to the system simulation model should be studied.

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