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Method of Operational Activities and Processes Optimization Design in Architecture

Xiaoxue Zhang¹, Aimin Luo¹, Gang Liu², and Junxian Liu¹

¹ Science and Technology on Information Systems Engineering Laboratory,
National University of Defense Technology,
Changsha, China

snowing1124@126.com

amluo@nudt.edu.cn

18674864900@163.com

² ChongQing Communication Institute,
Chongqing, China

liugang1109@126.com

Abstract. As the foundation and basis for developing architecture products and data, designing operational activities and processes is the key in architecture design. Current research lacks the optimization design method about them. To solve this problem. Firstly, this paper analyzed the data meta-models related to operational activities, proposed the process of optimal design of the operational activities and processes. Secondly, the objective function of the optimization of operational activities and processes are studied considering the time, success rate and cost. Thirdly, the process of simulation evaluation of operational activities and processes is designed, then we propose the method of how to convert activity-related architecture data into object Petri-net simulation model. Finally, three means of improving the operational activities and processes are given to arrive the optimal design objectives.

Keywords: Architecture, Operational activities and processes, Optimization, Evaluation.

1 Introduction

During the specific architecture design, the design of operational activities and processes includes many aspects, such as the decomposition of top-level tasks, the generation of operational activities and the optimization of the operational activities and processes. All of these mainly be conducted by operational commanders. The design of the operational activities and processes is the basis for the development of system view, service view and so on. Only after the operational activities and process has been established can systems and services supporting the operational activities and processes be followed. So, the design results are directly related to the completion of the entire operational objectives. In this way, the design of the operational activities and

processes is the most basic and crucial issue in the design of the Information systems architecture.

Currently, in the field of Operational activities Process design, the research focuses on two aspects: operational task decomposition and the generation of Course of Action (COA). Literature[1][2] studied a method of applying Hierarchy Task Net (HTN) planning to combat task decomposition and combat operations. Literature [3] put forward the concept of meta-activity, take meta-activity as the activity of atomic transactions in combat operations. The current methods of generation of course of actions can be divided into calculation-based methods and simulation-based methods. The COA generation based on the calculation method is divided into two kinds. One kind is based on mathematical programming, the other kind is based on the use of Artificial Intelligence (AI) [4][5]. The simulation-based COA generation method takes the generation of operational action plan as a simulation process, considers the factors that influence the plan when generation in the simulation process, and uses the simulation results to represent the COA plan [6][7]. In current research, there is still a lack of method to optimize the design of operational activities and processes in specific architecture design. This paper supposed that the operational activities and processes has been preliminarily generated, explored the evaluation method of the Operational activities Process using simulation model based on object petri-net, then studied the method of improving the Operational activities Process to achieve the ultimate optimal design goal. In section 2, we analyzes the data meta-models related to operational activities and puts forward that the optimal design of operational activities and processes includes three parts: the decomposition of operational tasks, the generation of operational activities and processes and the optimization of operational activities and processes. In Section 3, we put forward the goal of optimizing the design of operational activities and processes. Then, we study the simulation design of operational activities in Section 4. Finally, in Section 5, three means are given to optimize the process of operational activities.

2 Analysis Based on Activity Related Data Meta-Models

Architecture data meta-model standardizes the relationship between architecture logical data [8]. Among them, Activity is the core element, the design of other architecture data is closely related to Activity. Architecture operational activities Process design is mainly aimed at the optimization design of the data related to combat activities. Figure 1 constructs the activity-related data mate-model of the architecture. In Figure 1, the arrow with a solid arrow indicates the relationship; the arrow with a hollow arrow indicates the inheritance relationship.

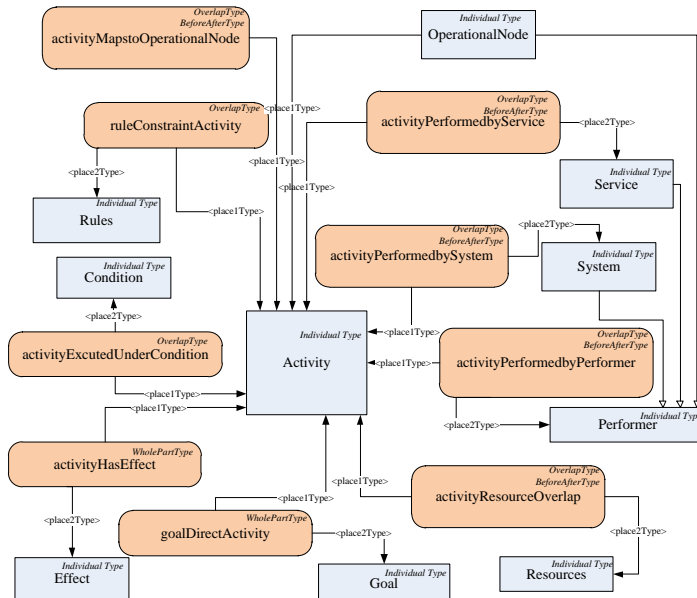


Fig. 1. Activity-related data meta-model in information systems architecture.

The data related to operational activities mainly include several types of information:

1. Performers of activity execution: including Activity, Performer, activityPerfomedbyPerformer, activityMapstoOperationalNode, etc. These data described that activities are performed by which combat command unit. Here, Performer can be the organizational unit, battle node, system or service that is responsible for the activity.
2. Conditions when activity executing: including Activity, Condition, activityExcutedUnderCondition. These data describes the information of state and condition when executing activities, including the preconditions described in the rules and the state of the activities will change after execution.
3. Rules of the activities: including Acitivity, Rule, ruleConstraintActivity. These data mainly describes the rules that activities need to fulfill when executing.
4. Goal of activity execution: including Activity, Goal, goalDirectActivity. These data mainly describe which mission objectives are fulfilled by the activity execution.
5. Consumption and output of Resource when activity executing: including Activity, Resource, activityResourceOverlap. These data mainly describes the relations between activities implementation and resource consumption or use. Resources can be divided into three types:
 - Consumable resources: the execution of activities will consume such resources, such as missiles.
 - Releasable resources: the execution of activities requires the use of such resources, but once the activity is completed, such resources will be released, such as missile vehicles.

- Sharable resources: Such as information resources, the implementation of activities has no effect on the resources themselves.

The process of operational activities and processes design includes three problems, as shown in Figure 2, First is how to decompose the operational objectives and the mission into executable atomic activities. Second is how to generate the Operational activities Process, that is, considering the resource constraints, the conditions and the execution rules of each activity, how to generate the sequence of executable combat activities, called as preliminarily Operational activities Process. The third is to optimize the Operational activities Process that have been generated, we need to evaluate the existing operational activities and processes, analyze the existing problems in the design, and then optimize the operational activities and processes and modify the activities-related design.

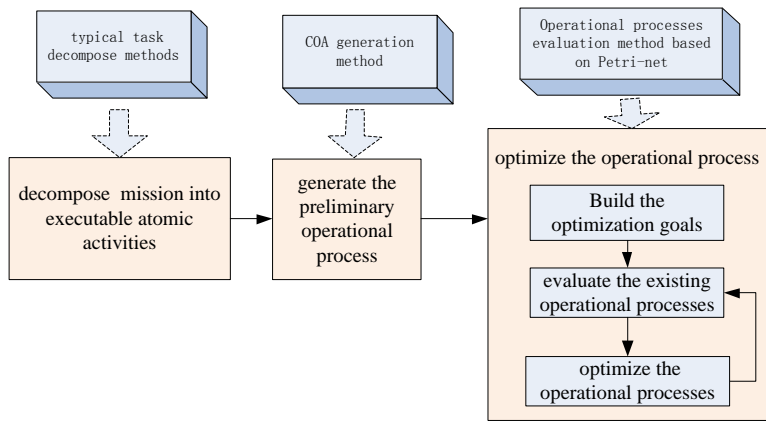


Fig. 2. The process of optimal design of the operational activities and processes.

3 The Optimization Goals of Operational Activities and Processes

After the operational preliminary process generation method is implemented, feasible operational activities and processes is obtained. How to improve the operational activities and processes is a problem that need to be solved in the optimization of operational activities and processes. In general, the indicators that optimize the design of the Operational activities Process include three factors: time, success rate and cost. For time and success rate, we can use the simulation method in Section 4. For the factors of cost. We can convert different types of resources into unified value.

The objective function value Z (BP) for a Operational activities Process includes a weighted composite of success rates, time, and costs, as shown in Equation 1. If the target value satisfies the set threshold $Z(BP) > \theta$, the process solution is considered as feasible solution. If the optimization method can increase the value of Z (BP), then

accept the optimization, otherwise, do not accept. The formula for calculating the objective function is as shown in Equation 2 to Equation 4, where w_i represents the weight of the indicator of number i . Before setting the weight of three factors, we need unified units and normalize each value. Relative to time and success rate of the indicator weights, the cost or resource consumption in the military information system has a lower weight value. The cost C in Equation 3 is obtained by weighting the normalized resources. The success rate V in Equation 2 and the time T in Equation 4 can be simulated by the executable model. Section 3 describes the design of the executable model and the design of the simulation process.

$$Z(BP) = \sum_{i=1}^3 w_i z_i(BP) \quad (1)$$

$$z_1(BP) = V(BP) \quad (2)$$

$$z_2(BP) = 1/C(BP) \quad (3)$$

$$z_3(BP) = 1/T(BP) \quad (4)$$

4 Simulation Process Design of Operational Activities and Processes

In the architecture design, the design result of the Operational activities Process use architecture model to represent, and stored by the architecture data. This section explores how to translate architecture data into an object petri-net simulation model. After the simulation model is established, through the simulation experiment, the result of the time and success rate of the operational activities and processes design can be obtained.

In constructing the simulation model using object petri-nets, we need firstly define the mapping relationship between the architecture data and the object petri-nets simulation model. The hierarchy of activities decomposition can be represented by object classes, and the sub-activities formed by decomposition are the core components of the object class. During model construction of an object class, we can use transitions to represent activities, and resources are represented by the attributes of the tokens in the location, while the conditions and rules for the occurrence of the activity are represented by the transfer function. Table 1 shows the correspondence among the Operational activities Process elements, the architectural data elements and the object petri-net simulation model elements.

Based on relationships between elements of logic data meta- model and elements of the object petri-net model, the process of constructing executable object petri-net is shown in Figure 3.

Table 1. the corresponding relationship among the Operational activities Process elements, architecture design elements and simulation model elements.

Operational activities Process elements	Architecture design elements	Simulation model elements in object Petri-net
The hierarchy of activities decomposition	Activity, WholePartType	object class
Sub-activities	Activity	transitions
Synchronization mechanism	Rule, ruleConstraintActivity	transitions, transfer function
Resource	Resource, activityResourceOverlap, Information	attributes of the tokens
Condition	Condition, activityPerformedUnderCondition	transfer function
Effect	Condition, activityPerformedUnderCondition	transfer function

- Step1: Build system model framework and OPN class library. Analyze Activity data items and the corresponding WholePart-Type, converted the activities that only have sub-activities without parent activities into the entire model framework; according to WholePartType and SuperSubType, abstract OPN model between Relationship, construct OPN class library framework.
- Step2: Determine the input and output ports. According to BeforeAfterType, determine the interaction relationships between different classes. According to activityProducesResource and activityConsumesResource, explicit interaction information. According to information and resource data items, clarify the characteristics of the interaction information, then determine the OPN model input and output ports.
- Step3: Establish the OPN framework model. According to BeforeAfterType description of activities, establish each OPN framework model. If one activity have sub-activities (judge by WholePartType), convert it to an object class, otherwise, convert it into switch. Then, connect the input and output ports in models with the corresponding transfers.
- Step4: Perfect the OPN model. Learn from the description of system performance parameters and information interaction by ruleConstraintActivity, measureOfTypeResource, activityPerformedUnderCondition, activityProducesResource and activityConsumesResource, combined with the description of Activity and transfer rules by BeforeAfterType and Rule, add the script function in the OPN framework, including Action function, delay function and event handling function to realize the related functions of each model.
- Step5: OPN model evaluation process. According to the established evaluation index system, add the relevant index data collection script to the model to complete the OPN model;
- Step6: Generate simulation cases and simulate. Add initialization function, instantiated function, instantiation of the top node model to generate the overall simulation case. According to the assessment acquirement, we can design simulation experiments, configure models for simulation, deal with the collected simulation data, and correlates these data with the evaluation index, then we can carry out the

evaluation of the Operational activities Process according to the pre-determined evaluation model. For complex functions that are not easy to be implemented by scripts, dynamic link library algorithms can be compiled with VC and called in the OPN model.

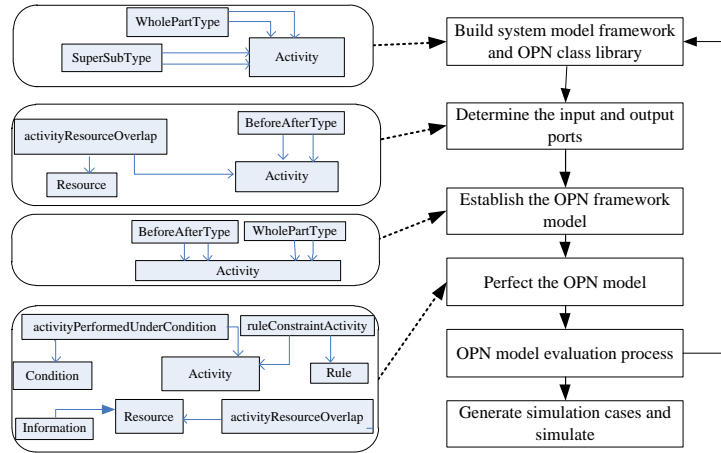


Fig. 3. Object petri-net simulation model constructing process based on data meta-model in DoDAF2.0.

According to plan generated by operational activities and processes, we can configure the action function of the simulation model according to the data of the architecture design, then run the simulation and get the simulation results. The simulation results include the execution time, success rate, and resource consumption over time of the solution.

5 Optimization Process of Operational Activities and Processes Plan

In the simulation experiment based on object petri-net, we got the execution time, success rate, and resource consumption over time of the solution. The optimization method is mainly aimed at the execution time, execution success rate and resource allocation in activities, so as to achieve the optimal objective function value of the entire operational activities and processes plan in section 3. Drawing on the method of business process re-engineering, considering the characteristics of the operational activities and processes, the optimization methods of operational activities and processes mainly include the following three kinds:

- First method: shorten the execution time of key activities to shorten the completion time of the whole process.

After generating the initial operational activities and processes, key activities that affect the execution time of the entire Operational activities Process can be found.

Compressing the execution time of critical activity can significantly reduce the overall execution time of the entire Operational activities Process.

- Second method: increase the parallel activities to improve the success rate of the completion of operational activities and processes.

Considering the uncertainty probability of a single activity, the total execution time of the processes can be obtained through simulation, and the impact of the success rates of different tasks on the program can be analyzed and compared. First, find activities that increase parallelism, as the number of resources allows. Then, based on the execution of the activities, execute the simulation, the simulation results show the sensitivity of each activity to the success rate. Find the most influential activity in the operational activities and processes, and try to improve the success rate of the influential activity.

- Third method: maximize the efficiency of resource use, to achieve the optimal allocation of resources.

In the case of spare resources are available, reallocate resources to various activities so as to maximize the use of resources in order to optimize the allocation of resources for operational activities. Under normal circumstances, there are two kinds of resource allocation situation:

- The resources required for activity are only one kind

After all operational activities have been met, the remaining resources can be optimal allocated. For example, if all the activities in a combat operations are satisfied, there are remaining reconnaissance resources A and firepower B, then we can search for activities that can be met by resources A and activities that can be met by resources B, then get the remaining resources A and B. Then we can obtain the optimal configuration of several feasible programs, choose the best feasible options to maximize the objective function, in this way, we can get the resource allocation program.

- When the activities can be completed using different types of resources

In this case, the resource allocation should be based on the success rate, time and cost of resource, then select the best matching solution. Under normal circumstances, the success rate of activities is the first factor to consider, followed by the completion time, and finally the cost of resource consumption.

The overall steps in the optimization of operational activities and processes are:

- Step1: Calculate the objective function value $Z(BP)$ of the plan. If the $Z(BP) > \theta$ is satisfied, then accept the scheme. Otherwise, go to the next step.
- Step2: Calculate the objective function value $Z1(BP)$, if $Z1(BP) > Z(BP)$, then accept the optimization; otherwise, reject;
- Step3: Calculate the objective function value $Z2(BP)$, if $Z2(BP) > Z(BP)$, then accept the optimization; otherwise, reject;

- Step4: Calculate the objective function value $Z_3(BP)$,if $Z_3(BP) > Z(BP)$,then accept the optimization; otherwise, reject;
- Step5: Generate new Operational activities Process plan and calculate the objective function value $Z_{new}(BP)$. If $Z_{new}(BP) > \theta$, accept the new process; otherwise, redesign the Operational activities Process and go to Step1 until the objective function value satisfies the threshold θ requirement.

6 Conclusions

The design of operational activities and processes is the key issue in architecture design. In this paper, we take insight in the problems about the optimization design of operational activities and processes, and analyze the three problems involved in the process optimization of operational activities based on the data meta-model. We also study the objective function of the optimization of the operational activities and processes, the simulation evaluation of the operational activities based on object petri-net, and the methods of improving the operational activities. Finally, the objectives of the operational activities are optimized. The next step will be studying the specific case applications and other optimization method for services and organizations.

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