Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 13 (20): 4133-4137, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.4133.4137

A Method of Analysis and Optimization on System Architecture

[1]Tingting Zhang, [2]Zhixue Wang, [1]Song Huang, [1]Liping Rao and [1]Wenjuan Xie
[1]Department of Software Engineering,
[2]Department of Technology of Command and Control, PLA University of Science and Technology,
Nanjing, 210017, China

Abstract: In order to simplify and optimize the complicated operational activity model OV-5 during the design process of architecture framework, this thesis put forward a model analysis and optimization method of operational activities based on the Colored Petri Net. First, the OV-5 model will be hierarchically decomposed according to the different business domains. Then, transform the operational activity model to the Colored Petri Net model and finally simplify the Petri net model according to different requirements. Though the performance of the Petri model, one can testify the effectiveness of the model simplification to realized the optimization of the operational activity model. After, the thesis testifies the model through the analysis of a case.

Key words: Architecture framework, operational activity, DODAF, engineering mathematics, colored petri nets

INTRODUCTION

Architecture framework is “the guideline and the principle of the design and evolution that restricts the structure of the components and their interrelationship”. (US. Department of Defense, 1997) In order to guarantee the standardized description of the architecture framework and hence the correct understanding, comparison and integration, the US army issued a series of description frameworks of the architecture, among which C4ISR2.0 (US. Department of Defense, 1997) in 1997 and DODAF1.0 (US. Department of Defense, 2003) in 2003 and ODAF2.0 (US. Department of Defense, 2009) are typical ones. These frameworks describe the architecture from different perspectives and each view contains a series of products. Here, products refer the diagrams, words and forms developed in the process of architecture framework description and each product stands for one focus in a view.

In the operation view, the operational activity product OV-5 mainly describes the hierarchical relations and information relations of the operational activities. The product reflects the process of task and the relationship with information flow. The process of structuring a product is usually determined by the task. However, such a method results in a too complicated operation model and thus makes it difficult to judge its reasonability. At present, the research in the reasonability of operation model mainly emphasizes the detection and elimination of the incoherence and conflict(Xiu and Luo, 2005; Luo and Jun, 2008). However, there is very little research into the simplification of the operational activity model. To simplify and optimize the operational activity model, the thesis advances an analysis and optimization method of the operational activity model based on the Colored Petri Net. First, the OV-5 model will be hierarchically decomposed according to the different business domains. Then, transform the operational activity model to the Colored Petri Net model (short as CP-nets) and finally simplify the Petri net model according to different requirements. Though the performance of the Petri model, one can testify the effectiveness of the model simplification to realized the optimization of the operational activity model.

MAPPING MECHANISM OF OV-5 AND CP-NETS

Hierarchical decomposition process of OV-5: OV-5 describes the items which include the operation to fulfill a mission task or business objective and the input-output relationship among different operation and in-and-out activities outside the architecture framework description. Action refinement is the core operation of the operation hierarch design whose basic concept is the process of degrading the basic units of high level in operation to that of lower levels and creating an operational activity hierarchical diagram of operation. The specific procedures

Corresponding Author: Tingting Zhang, Department of Software Engineering, PLA University of Science and Technology, NanJing, 210017, China Tel: 86-13062563872

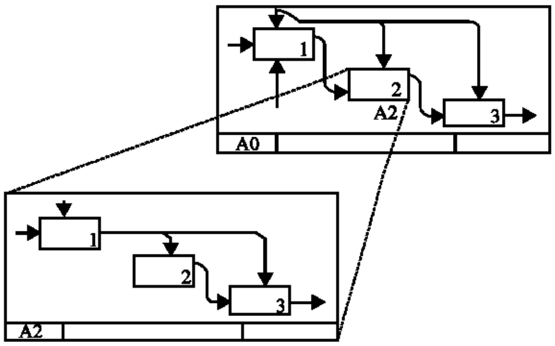

Fig. 1: Operational activity hierarchical model

include: first, analyze all the business domains that may involve in the operational activities (Fig. 1). That is to say, the general activities should be divided roughly into several small components according to the business domains; second, divide each component to even lower levels and replace with detailed activities (the set); third, keep the dividing until the very detailed operation design. To the undividable operations, we call them the leaf operations and we call the dividable operations as father operations.

The decomposed operations result in three relationship: Relationships of dependence, relationships of information flow and relationship of input and output. The process of operational activity goes as: data entering the operation process and process by operation and then output.

Mapping mechanism of OV-5 and CP-nets: In order to further analyze the structure of the operation product, map the hierarchical operation product to the dynamic model Colored Petri Net. Colored Petri Net is a net of high level and one can further abstract the place/transition system to expand the token of the Petri net to endow it with color set and type attribute which will combine the data structure and the hierarchical decomposition and thus to simulate the operational activities process and further simplify the model. Here, the thesis set several definitions of the Colored Petri Nets (Jensen, 1994):

Definition 1: Colored Petri Net: A six-tuple, $\Sigma = (P, T, F, C, I, O, M_0)$, among which:

- P and T respectively stand for the nonempty finite set of the place and transition system and satisfy $P\cap T = \phi$, $P\cap T = \phi$
- C = {C(p), C(t)} Stands for the color set, among which, C(p) stands for the colors sets concerning each place, C(t) stands for the color sets concerning the transition systems
- The set of colored place is $\bar{p} = \{<p, c>|p\in P, c\in C(p)\}$, colored transition set is $\bar{t} = \{<t, c>|t\in T, c\in C(t)\}$, I and O, respectively stand for the functional matrix of input and output. Then, $I = \bar{P}\times\bar{T}$, $O = \bar{T}\times\bar{P}$ (× is Cartesian product)
- M_0 stands for the beginning marking

The basic transition principle is: Taking advantage of the matching relationship between OV-5 and CP-nets to set the map of different elements. Transmit the operation diagram from the top level to the bottom level and all the operations have definite names and definitions. The transition principle goes as follows:

- **R1:** Information of the operation, namely the operation condition, is transformed to concerning place and token, in which the qualities of the information transform to that of the token
- **R2:** Operation will be transformed to t as events
- **R3:** Every activity must have the information input and output. Information input: the indispensable information which should be possessed before carrying out the activity which can be divided into two classes: External information and internal information. The output information: Information created by the activity which can be applied in other activity in the model
- **R4:** Object in the activity diagram transits to the token in the place
- **R5:** Relationship of time sequences and logic of the neighboring activity transmit to direct arc f
- **R6:** Due to the fact that the activity contains both father activity and leaf activity, this thesis introduces the concept of complicated transition and sub-net of Colored Petri Net. Thus, we can transmit the operational activity of the top level to the main Petri Net and the bottom level operational activity to the sub-net of the Petri Nets. Accordingly, the description in the Petri Nets can be divided into two sets: Basic transition t and complicated transition t'. The leaf activity will be the basic transition; the father activity will be the complicated transmission which has its own inner structures, behaviors and conditions. Add two place of p^s and p^f and two instantaneous transition (the operation time is zero) of the initiative transition t^s and the terminal transition t^f. P^s and p^f places represent the start and end of the sub-net.
- **R7:** Expand the Colored Petri Nets and added more port types, add the internal input/output ports to the complicated transition t' and add external input/output ports to the initiative transition t^s and terminal transmission t^f

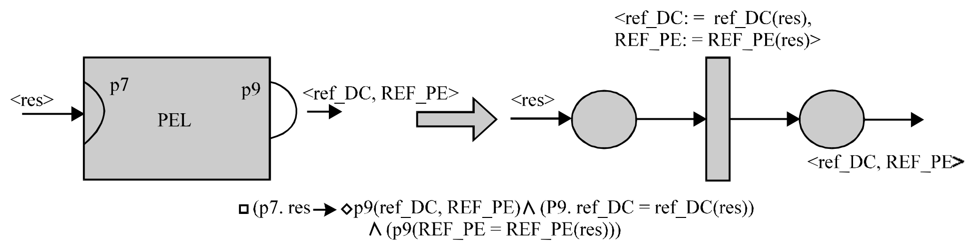

Fig. 2: Demonstration of activity transmitted to the colored petri nets

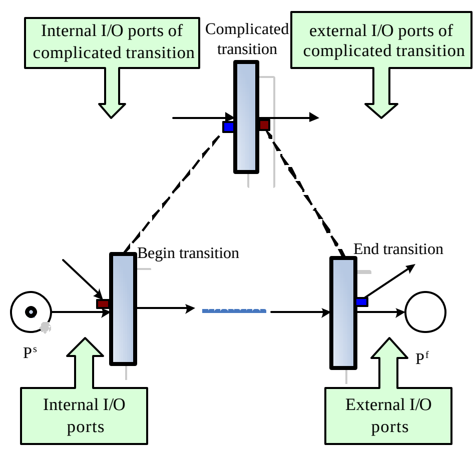

Fig. 3: Demonstration of the internal transmission of the complicated transition

- **R8:** Expand the token and add more types and properties of the token. When the token move, they will be with the added date information

Figure 2 and 3 demonstrate the transmission processes of Colored Petri Nets and the complicated transition.

OPTIMIZATION METHOD OF OPERATION MODELS BASED ON CP-NETS

In the process of the hierarchical decomposition, the total information process will be gradually complicated accordingly with more dependence and layers among the different activity, especially in the dispersed environment. In order to make it more convenient to analyze the reasonability of the activity process, we optimize the above mentioned CP-nets activity models in according to the different requirements. Generally, the simplification of models includes place fusion, transition fusion and arc addition and so on.

Merge and hide of model layers and irrelevant details to verification: In real life, operational activities are carried out according to their levels or business domains. The analysis of the activity only contains one or a few father activity and their leaf activity. In response to such situations, we can hide the inner structure of the sub-net to ignore the irrelevant details. In modeling, we concentrate on the according layer to make the activity model have a sound structure to make it convenient to analyze. In real practice, we won't perform the sub Petri nets. Instead, we use complicated transition t' to substitute and color the transition t' and thus we simplify the Petri net structure.

Mergence of the same structure: If the Petri net model has the symmetric quality, it means the operation has the same quality. We can color the place and transition in CP-nets to simplify the structure which mainly include two steps:

- To judge if there are similar structures
- Merge the similar structures

The algorithm for intra-overlap transformation:

Algorithm: intra-overlap-f

comment:

- $p \xrightarrow{f} p'$: That perform action f to state P to state P'
- E: a set consisting of the event
- λ: T>E a correlation function of event on trasition
- μ 0 a beginning mark
- S: a set consisting of event structure
- T: a set consisting of operation of S
- F: a set consisting of relationship of S
- NS: a set consisting of event structure which has simplify structure

Input: S1 = {P1, T1, F1, cd(p1), λ1, μ01}, S2 = { P2, T2, F2, cd(p2), λ2, μ02}
Output: NS = { P,T,F,λ,i0}
begin
NS = {};
If S1nS2 = ϕ
For (i = 1,i = j, i++)
if (λ1(t1i) = λ21(t2i)) then
T = T$\cup${T1i}
F = F$\cup${F1i}
Cd (Pi) = {cd(p1i)}$\cup$cd(p2i)
End if
End for
end if

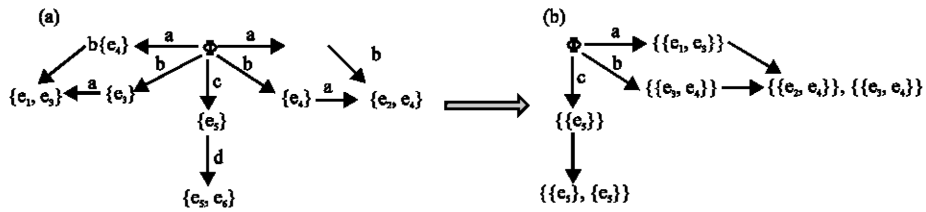

Fig. 4(a-b): Simplification of the events

The algorithm only maintains one sub-structure of the similar ones and there won't be similar sub-structures after simplification, as shown in Fig. 4.

Simplification of the state space: According to the basic principle of testing models, if the two sub-topics are the same in two conditions and the states are linked by one transition, then lift the two sides of the two states and combine them together without affecting the verification result while the state space will be decreased. The two states are called beam actions (Wang *et al*., 2007). In the process of Concurrent asynchronous activity in real life, there are numerous state and paths on the state map of the concerning Petri nets. If there are n independent beam actions, then there are n! arrangements. If one choose a typical independent action sequence, then other n!-1 sequence states will be combined which can be ignored in the model verification while the state space will be decreased even more. In the Colored Petri Nets, the description is in the form of net transition which is the abstraction and combination of transition and place. Set the $\Sigma_1 = (P_1, P_2, P_3)$ $\Sigma_2 = (P_1, P_2, P_3)$ and net transmission φ. If it can satisfy that $\varphi(P_1) \subseteq P_2 \wedge \varphi(T_1) \subseteq T_2$, then we call the net transmission φ as fold (Jensen, 1994) which is the transmission from place collection to place collection and the transition collection to the transition collection. Set the collection of place and their edges to ascertain the range of the fold.

Specific procedures of ascertaining the beam action:

- Allocate the independent actions
- Allocate the actions of the same state and concurrent execution and the actions of different states and concurrent execution and then turn to the same state, then determine whether they are the independent beam actions. If they are, merge the states in middle
- Take a single independent action as an independent beam action of a single action
- Take all the rest actions as a beam action of a single action

Through the beam actions, we merge the necessary actions and states and simplify the whole-state space to a partial state space to achieve the purpose of decreasing the space. The specific procedures go as follows:

- Each transition is caused by the concerning beam action
- In the whole-state diagram of the beam action, there aren't any independent relationships between any two action sequences on the path of the initiative state because the independent actions sequence is selected as the unique sequence and other sequences are invisible. Color the place and transition of the selected beam action
- In the whole-state diagram of the beam action before simplification, each path σ'_{ab} on the initiative path has its own path σ_{ab} in the simplified state diagram of the beam actions and σ'_{ab} equals to σ_{ab}
- In the simplified state diagram, there is no invisible beam action or transition between any two states on each path

CASE STUDY

Suppose there is an operational activity T and use the IDEF0 method to describe the operational activity which is demonstrated in Fig. 5.

Through the principle of mapping, transform the operation in Fig. 5 to the executable Colored Petri Net model, in which $A_i(i \in N, I \leq 5)$ transforms to T_i and $A_i(i \in N, i \leq 6)$ transmit to the concerning place and token, just like demonstrated in Fig. 7.

Finally, simulate the Petri net models in Fig. 6 and 7. we finally the result are coherent which testifies that the simplification of the prototype is effective and we have achieved our goals.

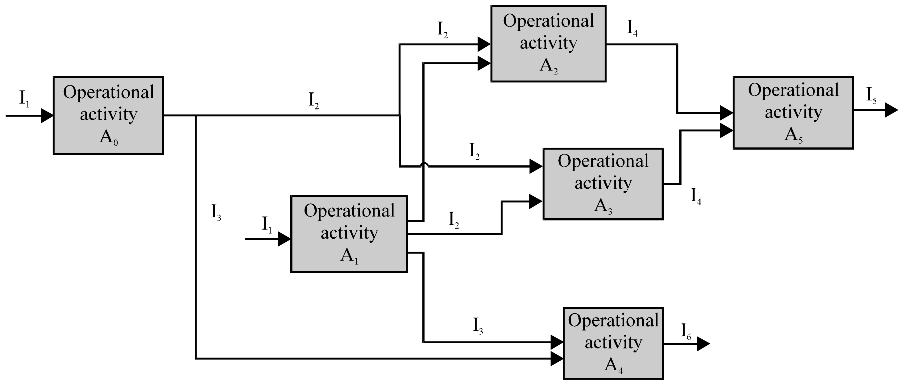

Fig. 5: Operational activity of task T

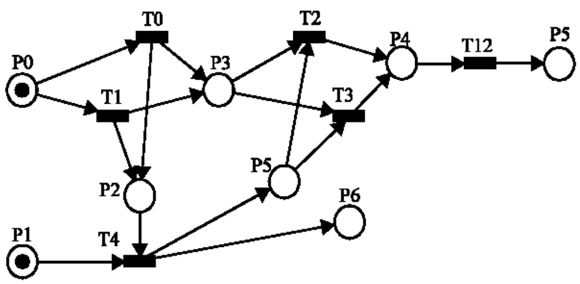

Fig. 6: Transmit the operation model to petri net model

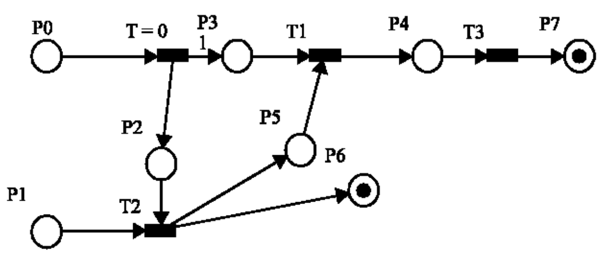

Fig. 7: Petri net model after simplification

CONCLUSION

This thesis research into three aspects: First, carrying out the hierarchical decomposition of OV-5 according to the business domains and then transmitting it to the Colored Petri Net model and proposing three simplification methods, namely the methods of complicated transmission to replace the leaf Petri net and simplify the proto Petri net model. Through analyzing the similar structure to combine the proto Petri model and establish the equality though independent relationship of action and accessible paths which makes it possible to have chosen visit to the state space and decreases the state space. Finally, we employ a case demonstration to illustrate the effectiveness of the model simplification method. Due to the limited length of the article, this thesis doesn't offer detailed analysis description of the Petri net model before and after being colored which can serve as the object of further research.

ACKNOWLEDGMENT

The research is supported in part by the National Natural Science Fund of China under the project number 61273210.

REFERENCES

Jensen, K., 1994. An Introduction to the Theoretical Aspects of Coloured Petri Nets. In: A Decade of Concurrency Reflections and Perspectives, De Bakker, J.W., W.P. de Roever and G. Rozenberg (Eds.). Springer-Verlag, Berlin, pp: 230-272.

Luo, A. and M.J. Jun, 2008. Consistency analysis method of entity realtionship of C4ISR architecture products. Comput. Appl., 28: 224-228.

US. Department of Defense, 1997. C4ISR architecture framework version 2.0. C4ISR Architecture Working Group, Department of Defense, USA.

US. Department of Defense, 2003. DoD architecture framework version 1.0. DOD Architecture Framework Working Group, Department of Defense, USA.

US. Department of Defense, 2009. DOD Architecture Framework Version 2.0. DoD Architecture Framework Working Group, Department of Defense, USA.

Wang, Y.X., J.Z. Wu and J.M. Jiang, 2007. Engineering Mathematics-symmetry and Action Refinement. Science Press, Beijing.

Xiu, S.L. and X.S. Luo, 2005. Logic and behavior validation of C4ISR architecture description. Syst. Eng. Electron., 27: 275-279.