

Research on BOM based Composable Modeling Method

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ABSTRACT

Composable modeling method has been a research hotspot in the area of Modeling and Simulation for a long time. In order to increase the reuse and interoperability of BOM based model, this paper put forward a composable modeling method based on BOM, studied on the basic theory of composable modeling method based on BOM, designed a general structure of the coupled model based on BOM, and traversed the structure of atomic and coupled model based on BOM. At last, the paper introduced the process of BOM based composable modeling and made a conclusion on composable modeling method based on BOM. From the prototype we developed and accumulative model stocks, we found this method could increase the reuse and interoperability of models.

Keywords: BOM, Composable Modeling, Atomic Model, Coupled Model, Model Structure, Model Description

1. INTRODUCTION

To further increase the reuse of simulation model resource, SISO (Simulation Interoperability Standards Organization) put forward the BOM (Base Object Model) specification based on component modeling method [1] and the standard of HLA (High Level Architecture) [2] in 2006 [3]. It provides an important mechanism for increasing the reuse and interoperability of M&S.

As BOM is based on HLA standard, it has brand indicating HLA's object model which results in the fact that most BOM based models are applying on HLA's platform, not considering any other platform. On the other hand, the present component modeling method based on BOM is developed on the two-level structure which includes component and federate. It belongs to the area of the composable simulation rather than composable modeling in the point of M&S. A true meaning component modeling method based on BOM should be developed on the three-level structure which includes atomic model, coupled model and federate. This structure could increase the reuse and interoperability of BOM based model and fractionize the model hierarchy.

2. BASIC THEORY OF COMPOSABLE MODELING METHOD BASED ON BOM

Composable modeling means that the simulation models reach an agreement on interface mapping, event type, parameter type and time scale according to relevant syntax description, attain the ability to send event and response the request, and correspond with each other finally. The essential of composable modeling is matching and mapping of different model interfaces.

In BOM based modeling method, the essential of coupled model is a coupled mode manager which provides a description to map the entity and event of atomic model to the entity and event of coupled mode and realize a connection between the interfaces of atomic models.

The basic theory of composable modeling method based on BOM composes of three sections. The first is formalism of BOM based coupled model, the second is the mapping mechanism [4] of BOM based coupled model while the third is principle of BOM based composable modeling method.

2.1. Formalism of BOM based coupled model

DEVS formalism pays attention to the description the hierarchy of model concept rather than model application. This paper integrated the characteristics of DEVS formalism, and put forward a formalism of BOM based coupled model.

This formalism could extend DEVS formalism, describe the hierarchy of model application and provide a theory support for BOM based composable modeling.

BOM based coupled model could be described by the following structure.

$$CBC = \langle Mi, OC, AC, IC, PC \rangle$$

Mi is a set of BOM atomic models;

OC is a set of object connection;

AC is a set of attribute connection;

IC is a set of interaction connection;

PC is a set of parameter connection.

BOM atomic model connection is realized by the relationship of publishing and subscribing while the attribute and parameter sets are defined in relevant object and interaction.

2.2. Mapping mechanism of BOM based coupled model

In the description of BOM based coupled model, the interface set of coupled model (F) is composed of the interface sets of multi atomic model (C). The relationship between the two interface set is showed as follows.

$$F = C_0 \cup C_1 \cup \dots \cup C_n, n = 0, \dots, N$$

The description of BOM based coupled model containing the information of object model describe the ability to interact throughout the coupled model with the publishing and subscribing ability supported by HLA's object model. And it's the common interface for the all atomic models to interact with models out of the coupled model, through relevant mapping mechanism which builds the mapping connection between atomic model interface and coupled model interface rather than piling up all the atomic model interfaces. The relationship is showed as a formula.

$$MAP: C_i \in C_n \rightarrow f_m \in F$$

In this formula, $i=0, \dots, n$; $n=0, \dots, N$; $m=0, \dots, M$.

C_i interface is one element in the interface set of atomic model C_n . MAP means mapping one interface C_i of atomic model to any interface f_m of coupled model. This mapping mechanism exists the multi-to-one connection which means different model interface could map to the same interface. So it enables the atomic models which have different syntax interface to interact with each other, resulting in the reuse and adaptability of atomic model interface.

2.3. Principle of BOM based composable modeling

When designing and developing simulation systems based on HLA in the simulation system developing environment, we usually compose simulation components to a federate, then connect the federates into a federation through RTI. Considering the complexity and performance of the real systems, this paper considers the federate as a high level component and model component as a low level component. Thus, the whole simulation system is composed of four levels including the BOM atomic model, BOM coupled model, federate and federation. The tree structure is a typical one.

The exterior function of the federate is mapped to the request function of the simulation model component, which means the connecting information among federates should be decomposed by hierarchy to the connection among BOM atomic models. Then, the connection among BOM atomic models could be mapped to the connection among the realizations of BOM atomic models which exist as DLL files. This technology doesn't change the realization of atomic models. In other words, the BOM based coupled model is a coupled model manager which manages a lot of atomic models and their realizations.

3. THE STRUCTURE OF BOM BASED COUPLED MODEL

3.1. The general structure

Through researching on the present popular simulation systems like FLAMS [5] and JWARS [6], we could find that they both construct their models by a composable method in order to increase the reuse and interoperability. On the other hand, their atomic models have their own unique functions and interaction interfaces which enable themselves could response to the change of outer environment.

But both of the two kinds of model structures have their inherent shortages. The first is that modeling and application can't be separated easily as the atomic model must be executed in the peculiar system. The second is the difficulty of modeling as the model development should follow the peculiar modeling standard. The last but not least is the weakness to compose by multi hierarchy. Considering these, this paper designed a general structure of BOM based coupled model as follows.

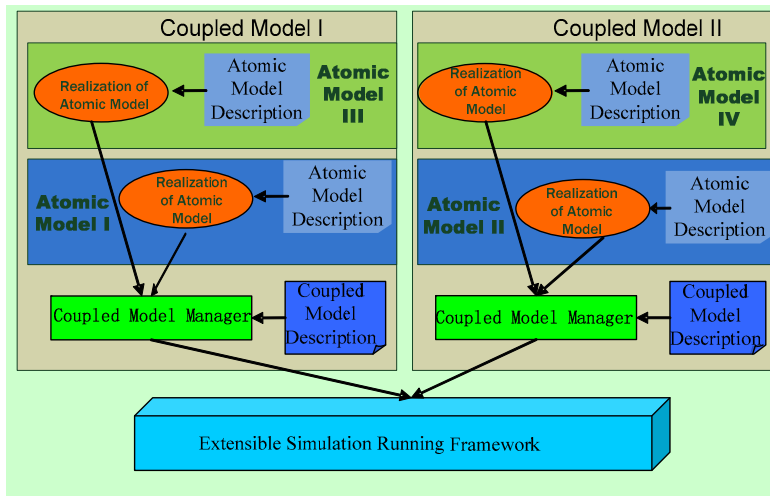


Figure 1. general structure of BOM based coupled model

As shown in Figure 1, each federate is made up of several BOM based coupled models while each coupled model is composed of several atomic models. As to each coupled model, the realization and application of the model are separated to increase the reuse of the model. Each coupled model administer a coupled model manager which manages the execution and data interaction of atomic models, and both of atomic and coupled models exist corresponding interface description. Compared with structures of FLAMS and JWARS models, this structure owns several advantages.

- Reduce the difficulty of model development while improving the efficiency

The development of atomic model realization should follow a very strict programming regulation in practice, and the coupled model manager is created by auto code generation and compiling technology. In addition, the model developer could just pay attention to the model development rather than the change and operation of simulation platform.

- Increase the reuse of the models

As the atomic models don't interact with simulation platform directly, we could just adjust the coupled model manager to use in a new platform when the model should be executed in different platform or simulation environment.

- Improve the model's ability to be composed

As the interact interface of the model is exposed outside, the atomic model could not only be executed in the federate directly, but also be composed in a coupled model to form a more complex model.

3.2. The structure and design of atomic model

The structure of BOM based atomic model mainly contains two parts. The first is atomic model description which exist as a XML file, describing the information of objects and interactions of the atomic model and the interface. The second is the realization of the model and correlative resource existing as a DLL module. Between the two parts, the model description is the basic one which reflects the dynamic behavior and states of the model, while the realization deriving from the description is the main part and reflects the practical behavior and active state of the model.

3.2.1 The design of the atomic model description

The description includes three sections: (1) Property; (2) Object Model Definition; (3) Configuration.

In the Property section, atomic model ID is the only identifier to define atomic model. Through the section, coupled model manager could identify the atomic model when executing.

In the Object Model Definition section, it includes the definition of model's objects and interactions such as name, publish and subscribe type, attribute and parameter information and so on. Through the section, modeling framework generates the code frame of atomic model's realization.

In the Configuration section, it contains the data configuration information which indicates the data direction about entity's update and event's interaction. The value of OutofComponent represents whether the updating data of the atomic model should be sent outside the coupled model, and the value of SelfReflect represents whether the atomic model should communicate with the other objects abstracted from the same entity class while the value of OtherModel represents whether the updating data of the atomic model should be sent inside the coupled model. The coupled model manager could filter and distribute the data inside the coupled model effectively with the Configuration section. This method avoids the distribution of redundant data and realizes the control synchronization of data flow in one step inside the coupled model.

3.2.2 The design of the realization of atomic model

The form of the realization of atomic model is a DLL format which is derived from the code framework of atomic model. This code framework is a user based model framework built by model users through a special modeling rule [7], and it could compute, update and interact the atomic model. The structure of the code framework is shown as Figure 2.

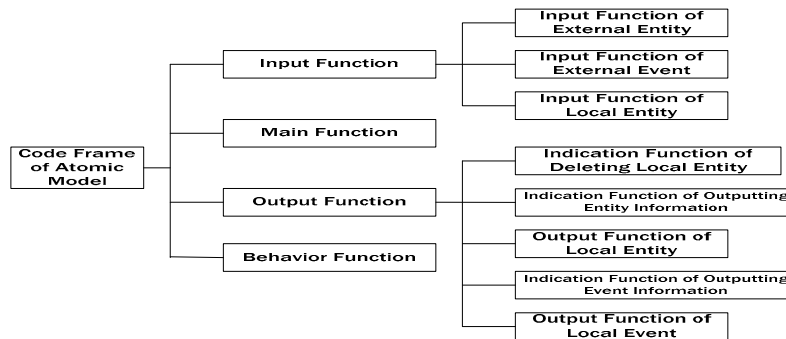


Figure 2. Structure of the Code Framework

3.3. The design of the coupled model

As the realization of atomic model is designed to be passive to interact, each model doesn't interact with the others forwardly. In this mechanism, coupled models search and apperceive the state change of user models through the interface function, get correlative data and send them to interested models. The factual executive tool is the coupled model manager who is in charge of the creation, update and release of atomic model entity, and the filter and distribution of the data inside and outside the coupled model. Coupled model manager is auto generated by mapping the coupled model description while the description is generated by model developer through composing the atomic model description and user configuration in the composable modeling framework. Thus, the BOM based coupled model includes two parts: coupled model description and coupled model manager.

3.3.1 The design of coupled model description

Besides the basic information, coupled model description mainly contains three sections: (1) Model Identification; (2) Compounding Relation; (3) Configuration.

In the Model Identification section, it reflects the basic information and identification of coupled model, such as type, name, modifying time, ID and the name of coupled model manager.

In the Compounding Relation section, it describes the relationship among the atomic models inside the coupled model, decides the primary and secondary order and the number of the atomic models.

In the Configuration section, it contains all the direction configuration of the data flow inside the coupled model, which decides the distribution and management of the data inside the model.

3.3.2 The design of coupled model manager

The form of the coupled model manager is a DLL file which is auto generated through compiling the coupled model code framework. The code framework is generated by mapping the coupled model description.

The coupled model manager includes five modules: (1) Coupled model managing module; (2) Atomic model managing module; (3) Message mapping module; (4) Published object mapping module; (5) Subscribed object mapping module.

a) Coupled model managing module

Coupled model managing module is responsible for corresponding the other modules, and communicating with the interface of the federate framework KD-XSRFrame. KD-XSRFrame is a framework for the federates' execution and join the federation through loading all the coupled models. Coupled model managing module could access and control the atomic models by listening a port naming ListenToSimEvent. The common functions are as follows: Receive the interaction; Send required interaction; Update the attributes of publish objects; Reflect the attributes of subscribe objects and Advance the simulation time.

b) Message mapping module

The Message mapping module realizes the mapping between the events inside the atomic model and interactions in HLA, packing and unpacking of the data in the interaction. It builds a HLA interaction matching every event in the atomic model to realize the conversion between the events and interactions.

c) Published object mapping module

The published object mapping module realizes the mapping between the outputs of the atomic model entity's state and the attributes of HLA's objects, as well as the packing of update data. A publish object maps an atomic model entity, so there is only one publish object in an atomic model.

d) Subscribed object mapping module

The subscribed object mapping module realizes the mapping between the entities outside the coupled model that atomic models concern and the attributes of HLA's objects, as well as the unpacking of update data.

e) Atomic model managing module

The atomic model managing module is in charge of the creation and maintenance of all objects abstracted from atomic models, and manages the whole life cycle.

4. REALIZATION OF BOM BASED COMPOSABLE MODELING METHOD

The realization of BOM based composable modeling method comprises two processes, the assemblage of the model description and realization of atomic model. The first is realized by the white box way and the method is that model developer configure the information manually and generate the coupled description through the description of atomic model and his own demand in Composable modeling framework. The second process is realized by the black box way and the method is that it creates a coupled model manager which could manage and maintain the realizations of atomic models. The graph Figure 3 below shows the two processes.

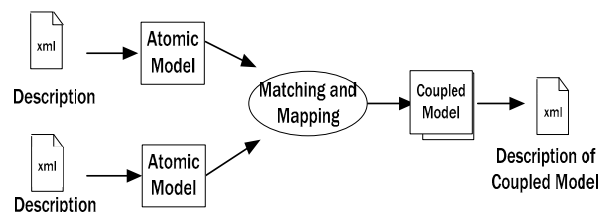


Figure 3. Composable Modeling Process

4.1. Assemblage of the model description

As discussed above, the coupled model description comprises of three parts, Model Identification, Compounding Relation and Configuration.

Model Identification is specified by model developer first of all, including the name, ID and so on.

Compounding Relation is specified by model developer too, but the composition is provided by the description of atomic model. After creating a new coupled model, model developer must specify the composition and compounding Relation, like which atomic model is the primary model and the whole number of the atomic models.

Configuration information contains the flow and order of update data inside and outside the coupled model. The information is specified by model developer in Composable modeling framework and the aim is to regulate the working rules and the bound of data flow inside the coupled model. There are three kinds of configuration information. The first kind specifies the primary atomic model which could update itself first in a simulation step. The second kind specifies the updating destination of each atomic model's object attribution, and the destination contains the other object abstraction of the same atomic model, the objects of other model in the coupled model and outside the coupled model. The third kind specifies the sending destination of each atomic model's interaction, and the destination is the same as the second kind.

Generally speaking, the coupled model description is composed by the white box way. Model developers configure and specify the relevant information in Composable modeling framework, finally compose the description of atomic model into the coupled model description.

4.2. Assemblage of the realizations of atomic models

The key technology in the assemblage of the realizations of atomic models is how to manage the realization of atomic model and the essential is creating a coupled model manager which will manage the creation and deletion of atomic models, updating of entities and interaction of events.

Before creating the coupled model manager, Composable Modeling Framework need to load the coupled model description in which includes all the relevant atomic model information. Based on the information and the code templates of coupled model manager, Composable Modeling Framework can auto generate the code frame of coupled model manager through XSLT technology, and the code frame can compile itself and generate the coupled model manager.

The creation of coupled model manager reveals the idea of black box composing. That is, Composable Modeling Framework doesn't understand the structure and realization of atomic models; it creates a coupled model manager to manage atomic models through the interfaces of the models.

5. CONCLUSION

With the development of simulation technology, the requirements for modeling are increasing and traditional way of modeling is out of time. This paper put forward a composable modeling method based on this actuality. Based on the method, we developed a prototype of BOM based coupled modeling framework by QT programming which is used to help model developer construct BOM based coupled models. The prototype named BomConfig got four functions.

a) Composable Modeling

Model developer could compose different atomic models to the coupled models through BomConfig.

b) Model Editing

When composing, model developer could add, delete and revise the attributes of the models if necessary through BomConfig.

c) User Configuring

BomConfig support model developer to configure all configuration description in order to generate coupled model manager.

d) Auto Generating

BomConfig could generate coupled model manager code framework through XSLT, the Coupled model and atomic model description. The coupled model manager is auto compiled from the framework.

From the prototype we developed and accumulative model stocks, we found this method could increase the reuse and interoperability of models.

Concerning the prospect of this method, this paper is just a beginning and there are a lot of works and problems need to be solved. Below are several points which we will work on next.

a) The formalism of coupled model doesn't support multi-level modeling and the coupled model composed by this method is up to include two levels. We should increase the modeling hierarchy.

b) At this moment, the initial data of the models are awarded at the beginning of simulation execution, but the fact is the simulation need append new data in the running process of simulation.

c) We didn't emphasize on the parallelism of models when designing the coupled models.

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