The Research of Component Based Integrated Modeling and Simulation Environment

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Abstract

In this paper, an component based integrated environment for centralized/distributed/parallel simulation (CISE) is proposed which is built upon advanced technologies such as Component, MDA, DEVS etc. Firstly, the comprehensive analysis on deficiencies of the HLA based simulation is presented. Accordingly, the primary goals of CISE are given which realize the reusability and interoperability in M&S, also support both the evaluation style simulation and the process demonstration style simulation. The key concept of CISE is component based modeling in which communication among components is achieved via ports. CISE provides a normative description system based on the advanced theory “separate model from experiment”, and use platform independent description criterions to realize the integrated environment. The functions of CISE: graphic modeling management, model component description, simulation management, adapter management, public resource management are all in detailed explained. Finally, the progress of key technologies and classic application are introduced, and the advantages of CISE are summarized.

Key words: model component; integrated modeling and simulation environment; experiment framework; simulation adapter;

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1 Introduction

Since the DOD M&S Master Plan was published by America Defense Ministry Office (DMSO),HLA has became a hot research topic all over the world, especially in military simulation field. Simulation application based on HLA have been proposed which played important roles in the procedure of demonstration, manufacture, evaluation and training for weapon developments and filled up the technology gap among continents.

HLA is regarded as the milestone of the interoperation in distributed simulation, while its limitations and deficiencies were cognized gradually along with the development of simulation technologies and applications. For example, for the reusability and independency on binary level, the HLA has some shortages due to its object based modeling rather than component based modeling. Moreover, HLA is more suitable for procedure and demonstration style simulations which emphasize the similarities both in function and function structure between simulation system and physics system, such as the simulation of war procedure and training. But for simulations focusing on result relatively, emphasizing the similarity in function, but neglecting the consistency between simulation system and physics system, such as Monte-Carlo based simulation, HLA can not satisfy.

The disadvantages are as follows:

(1) Slow response of simulation system. The ratio is always limited according to time cost in network delay and nodes. Consequently, the operation in most of these simulation systems takes half an hour or more to complete one cycle. The usability of the system in scheme comparison and parameter optimizing is doubtful in terms of this response speed;
(2) Low reliability of simulation statistics. According to the Monte Carlo Theory, only with enough testing samples can achieve certain level of reliability. Therefore, due to slow response of HLA based system, testing samples on certain state are generally limited, which result in a low level of statistic reliability.
(3) Difficult to ensure the irrelevance among the simulation samples. According to the Monte Carlo rule, the random sample's independency and irrelevance should meet the standard, technically, it's easy to create a random number serial which accord with required independency and irrelevance, while it's hard to achieve many number serials of this kind unless through elaborate planning.
(4) Bad reusability of simulation resources. The HLA simulation resources can only be reused on the application level, namely on the level of federal members, which can not satisfy the reusability of model resources consisting of simulation applications on the elaborate granularity.
(5) Complex management of simulation system. As to the HLA based distributed simulation system, the cost will be increased along with the increasing nodes, the increasing complexity of strengthening development, adjustment, operation, maintenance and data management.

In the application point of view, it's not correct to connect HLA with simulation system setup. Being the milestone in realizing simulation interoperation, HLA has its application scope, it is not a perfect structure fit for all application types.

To make up for insufficiencies of HLA in analyzing evaluated simulation, the parallel simulation technology based on advanced calculation gets more and more attention in recent years, in which PDES technology gains special attention. The SPEEDES (Synchronous Parallel Environment for Emulation and Discrete-Event Simulation) which was funded and developed by America Defense Ministry is a typical case. However, parallel simulation has deficiencies in these aspects: difficulty in building quadratic modeling, complexity in programming and debugging, restriction to software and hardware platform, therefore, our final goal is to design a kind of brand new simulation software which can combines the advantages in distributed, parallel and centralized simulation, and fits for all kinds of simulation. Accordingly, we develop the Component based centralized, distributed and parallel Integrated modeling and Simulation Environment CISE.

The characteristics of CISE are as follows:

(1) CISE was based on the formal description of discrete event model specification------DEVS which was proposed by professor Zeigler from

the University of Arizona of the United States. Specific forms of implementation was simplified to make the simulation operations easy to meet the "components" methodology.

(2) By Adopting MDA technology and focusing on model with integrated development, CISE can be operated in single machine，HLA/RTI and Parallel Simulation Platform(PSP) through adapter without complex programming. Thus it can simultaneously support the simulation of analyzing assessment and battle process etc.

(3) The development mode which based on components supports the succession and combination of model components.

(4) CISE provides model-independent advanced engine which supports fixed period and event dispatching

(5) CISE is in accordance with advanced simulation theory, it provides rules on experiment framework.

(6) CISE Adopts visible modeling technology, the definition of model components and simulation system development were done through windows and figures. The components output can be observed at any moment during simulation process, and the statistics are been outputted as charts and tables.

(7) The initialization files (such as HLA FOM etc) which are required by parallel and distributed platform are automatically created. The deployment of simulation modes can be automatically supported.

In fact, the core concept of CISE is “component” and “integration”. The former concept emphasizes that CISE is based on components technology. The entity model is been developed by other special software and then is integrated in CISE model framework. The other concept emphasizes that ① CISE supports integrated model development and the platform (centralized, parallel and distributed) is optional in simulation system development ② being an integrated simulation environment in operation, analyzing and assessment, CISE has complete function.

2 Core concepts of CISE

2.1 Model components

Component is often mentioned in information field, to be brief, component is the software entity in accord with rules. It features on binary system’s reusability, plug and play, independency and easy maintenance etc.

The definition of CISE model components takes reference of components basic theory in information field. Fig.1 shows the model components. In the exposed ports, the input and output ports are optional while other ports are defaulted by system.

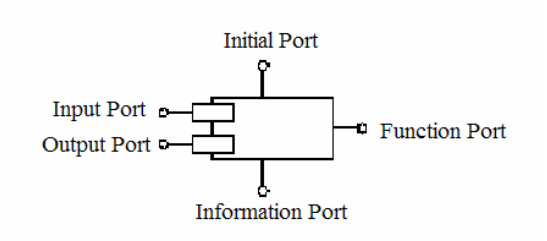

Fig.1 the Model Component

Input port: The input connection for the model components.

Output port: The output connection for the model components.

Initialization port: the initialization information connection for the model components.

Function port: The function transferring connection for the model component through which simulation engine accomplishes function switch.

Met message port: The function of dispatching template information can be achieved through this port, together with input and output ports type and property information etc.

In CISE, the model component is made up of 3 layers, basic model components, application model components, and application model components example from up to below. The dominant existence form is based on XML file and its corresponding DLL/COM, both of them make up of “model components” which is called in CISE. The layers are showed as Fig.2.

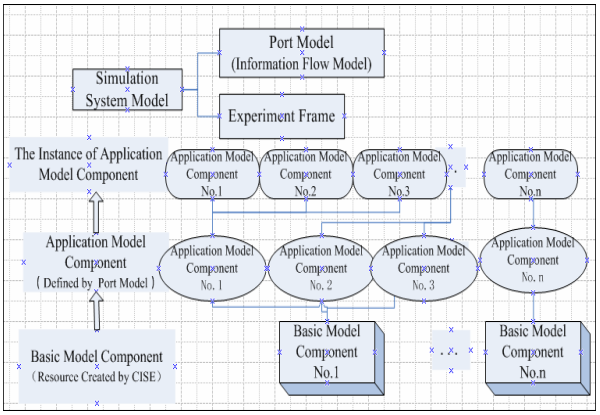

Fig.2 the layers of Model Component

Take a simple example to illustrate the idea mentioned above. Suppose we develop a multi-airplane rivalry simulation system with an established component which named plane, in this system airplane model A and airplane model B are in rivalry situation. Thus:

(1) Plane is the basic model component

(2) Interface model setup. Two basic model components A and B with different initialized ports are instantiated. A and B, the applied model components, are input and output mutually.

(3) Experimental framework setup. Define the instantiation condition and instantiation number of A and B, forming the experimental framework. Each instantiation is called application model component.

(4) The multi-airplane rivalry simulation system consists of the interface model and the experimental framework aggregation.

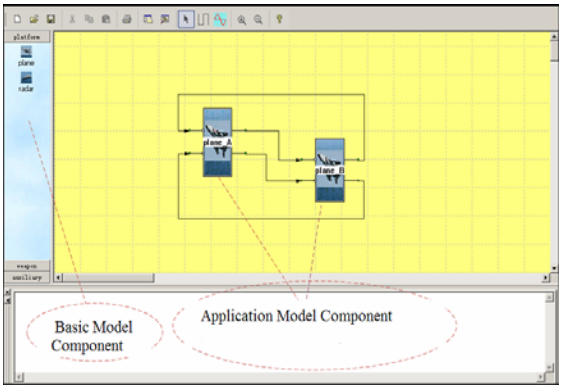

Fig.3 the example of CISE Application

2.2 Port

Port is often used in describing components, it is the communication system and links between components. Port could describe the dependent relations of components on the environment and output ability. The function independency and the inner logic of components are realized through the port.

Practically, port is the abstract data by which components exchange information. its corresponding data type is user-defined. The output port information from one component can be shared by other random multi-components; this is one to multi reflection. It is showed as Fig.4.

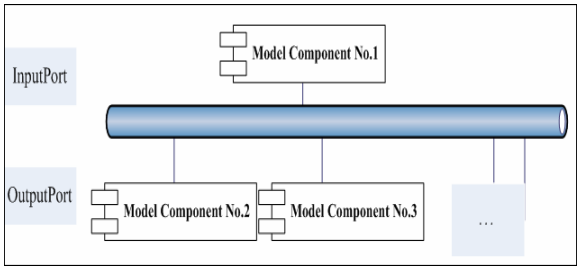

Fig.4 Port Connection

Port is classified as status port and event port according to the information types. The information from status port is durative with certain status such as the location and speed of missile and so on; while information from event port is status-less and abrupt such as the event of missile launch and knockout. Different port types are reflected as different functions in model components code frame.

2.3 Standard system description of CISE

The standard description system of CISES is the foundation for the whole system.

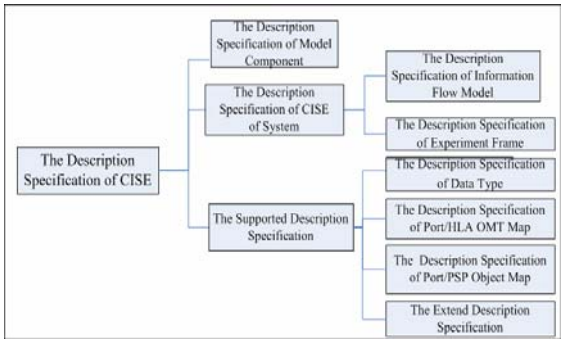

Fig.5 the description system of CISE

All the criterion in CISE is described by XML, the functions are as follows:

(1) Create the code frame of components and adapter.
(2) Serve as the input of simulation engine.
(3) Serve as the initialization and configuration information of CISE.

The example of XML Description File are showed as Fig.6.

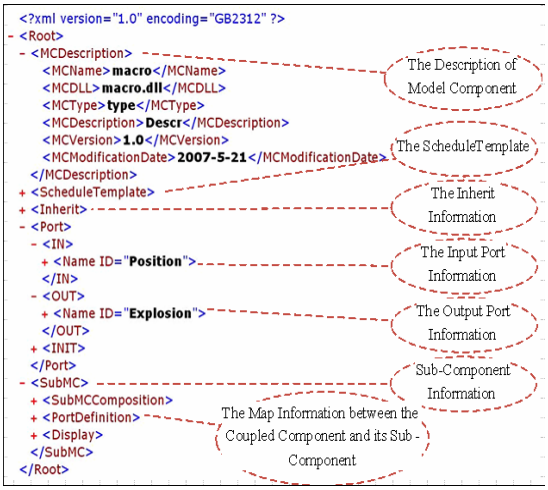

Fig.6 example of XML Description File

2.4 Experiment framework

The theory “the separation of Model and experiment” which was proposed by Oren has greatly influenced the design and application of simulation software. This theory stresses the separation of system model and experiment framework, system model defines the dynamic and static state while experiment framework defines the experiment condition under which the model can operate and produce output. Multi-framework can be created as for the given system model, in this case, different simulation experiment can be done by only modifying experiment framework rather than amending the experiment model.

The modeling of CISE follows the system modeling theory of " the separation of model and experiment framework”, the definitions in experiment framework are as follows:

(1) The control information of Simulation running, such as simulation time and operation frequency.
(2) The instantiation information of Application model, such as the instantiation’s setup time, time intervals, (fixed value or chance distribution) and batch quantity (produced in one go).
(3) Initialization information defines the initialization port information of the application model components.
(4) The information of Port observation and value statistics defines the port value and its statistics which collected in the simulation process.

The experiment framework applies the XML language according to the standard system description of CISE.

2.5 Simulation Engine

Simulation engine which fulfill the function of driving the model components to operate, is classified as centralized and distributed engine according to its expression form, the former engine exist in a powerful-function central engine, managing the operation of model components in a union, while the other engine also has a local engine that performs the dispatching task among the inner incidents in accordance with the central engine, supporting the simulation system to operate normally. The two kinds of engines cut both ways, the strong points of centralized engine is its favorable consistency and in line with "program realization and logics separation" rule. While distributed engine lies in its good flexibility due to its occlusive software entity.

We adopt centralized engine in the design of model components, the input includes:

(1) The congregation of Model components, that is the assemblage for all the model components used in simulation system.
(2) The port connection relationship of the application model components which is the message flow relationship of the application model components.
(3) Experiment framework.

The Simulation engine of CISE adopts discrete event simulation method， which can transfer frame-period component and event component.The biggest problem in realization of simulation engine should be the unlocking management of simultaneous events, for example, how to deal with the order of multiple events which happen at the same time. In the realized simulation engine, the unlocking management system needs to scan the information flow model, the rule is: events associated with A is of higher priority than

those associated with B on condition that the status output port of A is the input of B. As to those with many model components, the priority should be determined according to special unlocking calculation method.

2.6 Adapter

Adapter is used to convert the model component interface of CISE to other appointed platform (such as HLA/RTI, PSP) interface. Adapter technology is the core skills to realize integrated modeling.

The modeling of CISE takes reference of the MDA theory and the description standard takes no connection with operation platform, it can operate by mapping into appointed platform through adopter. The basic progress of Adapter is as Fig.7 showed.

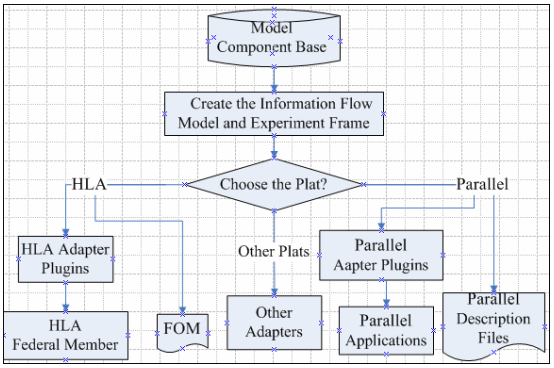

Fig.7 basic progress of CISE Adapter

Currently, we have realized the automatic creation of HLA adapter plug-ins and PSP adapter plug-ins, and we are able to use the simulation system which was created by ISE to operate in single-machine, distributed and parallel environment without manual programming.

3 The structure and major functions of CISE

3.1 CISE functional hierarchical structure

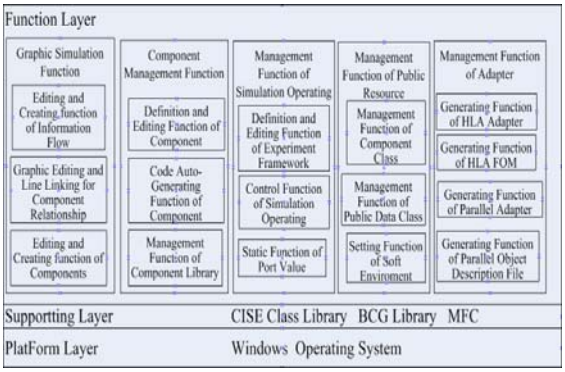

Fig.8 the functional hierarchical structure of CISE

The simulation operation platforms such as HLA/RTI, PSP etc are not the basic components of CISE, but rather, exists as extended modules.

The major functions of CISE are described as follows:

(1) The function of Graphic Modeling

Through the operation method of VISIO software similarly, CISE provides a grouping-display mode for model components, management of application model components (setup, delete, edit etc), graphic edit etc (move, link, enlarge, decrease etc) and realizes the setup and edit of information flow model and combined model.

(2) Management function of model components

CISE could define the inherited relationship, the port and the template of model components interactively. Also, the XML file which is according with the description standard could be created automatically. Then the code frame could be made with the XML file, after the modeling of entity model in the frame, The created DLL/Com with the XML file make up of the whole structure of model component.

(3) The function of Simulation management

Defined interactively, the experiment framework which connected with message flow is served as the input of the simulation engine. Meantime, the appointed port value can be observed and counted automatically according to the statistics from the experiment framework. Simulation control functions include the operation of start, pause, resume, stop etc.

(4) The function of Adapter management

The input which generated by the adapter includes the files of model component description, information flow, experiment framework, port and simulation platform mapping. Currently, the automatic creation of HLA adapter and parallel simulation adapter can be achieved in CISE.

(5) The function of public resource management

We realize the deployment of CISE software environment, includes: the display mode, the window layout etc, meantime; we can achieve the management of CISE public resource, the setting and editing of components category, data type etc, the application environment and interface are in accordance with customers' demands.

3.2 The key technology of CISE realization

Many new concepts and new methods have been absorbed in to the design and development of CISE, the key technology includes:

(1) The formalized description technology of model components.
(2) The inheritance and combination technology of model components.
(3) The simulation engine realization technology of supporting multi-dispatch systems.
(4) The formal description and visual modeling technology of message flow models.
(5) The separation technology of system model and experiment framework.
(6) The automatic generating of adapter for different simulation operation platforms.
(7) The technology of parallel simulation framework.
(8) The integrated technology of CISE.

3.3 The typical application process of CISE

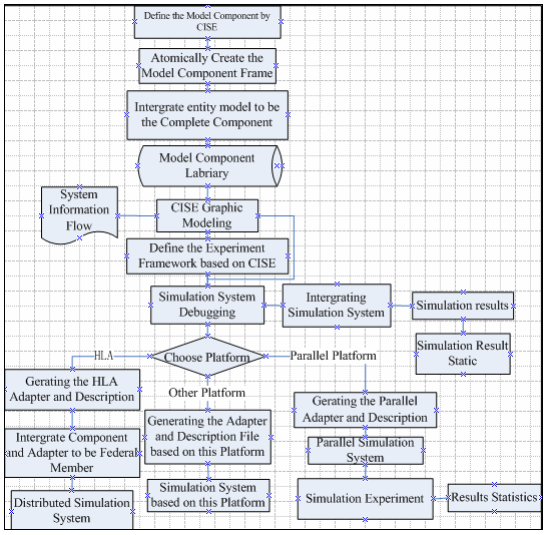

Fig.9 the Simulation Progress of CISE

(1) As for the description method of model components and message flow model which are independent from the simulation platform, model components' is better in reusability.
(2) Visual graphic modeling, we can get what we see in the simulation system
(3) Perfect function of integrated Modeling, simulation operation and statistics analysis.
(4) Easier developing and debugging, the distributed/parallel simulation system can be made directly after the debugging of single PC automatically, and it is with high efficiency.
(5) Different aims can be obtained through this simulation system which developed by CISE.Centralized/parallel simulation centers on result and distributed simulation emphasizes on process and demonstration both can be achieved easily.
(6) The Simulation system of CISE has strong usability, easy management method and low cost of system development.

4 Conclusion

CISE is an attempt we made in integrated modeling. From the tentative application we find that the modeling simulation environment has achieved the expected goal in integrated modeling and model reuse etc, however, it still needs improvement in the following aspects:

(1) The adaptability for multi-computer platforms. Currently, we use much windows technique to

implement the model components and the simulation engine, while the predominated high level simulation platform adopts more of Linux assembly calculator server, consequently, the core of CISE (model component and simulation engine) should consider the ability of transplant into Linux.

(2) The modeling combination of CISE and UML. From CISE port modeling to entity modeling, UML serves as a wonderful technique for extending CISE modeling due to its well definition, powerful function and general application features.

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