An extended HLA multilayer federation integration architecture for multidisciplinary collaborative simulation

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Abstract
The development of complex products is essentially concerned with multidisciplinary knowledge. Running on Internet\( ^{1} \) integration based on multilayer federation architecture and dynamic reuse of simulation resources are the major difficulties for complex product collaborative design and simulation. Since the traditional Run-Time Infrastructure\( ^{1} \) RTI\( ^{1} \) is not good at supporting these new requirements\( ^{1} \), an extended high level architecture\( ^{1} \) HLA\( ^{1} \) multilayer federation integration architecture\( ^{1} \) MLFIA\( ^{1} \) based on the resource management federation\( ^{1} \) RMF\( ^{1} \) and its supporting environment based Service-oriented architecture\( ^{1} \) SOA\( ^{1} \) and HLA\( ^{1} \) SOHLA\( ^{1} \) are proposed\( ^{1} \). The idea and realization of two key technologies\( ^{1} \) the dynamic creation of simulation federation based on RMF\( ^{1} \) TH\( ^{1} \) RTI\( ^{1} \) an extensible HLA runtime infrastructure\( ^{1} \) RTI\( ^{1} \) used at Internet are emphasized. Finally\( ^{1} \) an industry case about multiple uni\( ^{1} \) MU\( ^{1} \) is given.

Key words\( ^{1} \) complex product\( ^{1} \) SOA-Based HLA\( ^{1} \) SOHLA\( ^{1} \) multilayer federation integration architecture\( ^{1} \) MLFIA\( ^{1} \) multidisciplinary collaborative simulation\( ^{1} \) resource management federation\( ^{1} \) RMF\( ^{1} \)

0 Introduction

The mechanism\( ^{1} \) functions\( ^{1} \) structures and development of complex products are complicated and concerned with multidisciplinary knowledge and require an approach of collaboration among product development teams and organizations\( ^{1} \). Collaborative design and simulation have become powerful supporting techniques\( ^{1} \). High level architecture\( ^{1} \) HLA\( ^{1} \) has extended its application range from military field to civil producing industries. Several integration architectures based on HLA have been proposed\( ^{1} \) such as static single federation structure\( ^{1} \) MF\( ^{1} \) alterable single federation structure\( ^{1} \) and multi-federation system structure\( ^{1} \). However\( ^{1} \) some deficiencies in the HLA simulation system\( ^{1} \) still exist. For instance\( ^{1} \) HLA is not compatible with the standards and technologies in other domains\( ^{1} \), especially the web technology\( ^{1} \) HLA-based simulation may be blocked by firewall\( ^{1} \) which even makes simulation fail. The above deficiencies make it hard for HLA to get a deeper development in the field of collaborative simulation of complex product design.

Service-oriented architecture\( ^{1} \) SOA\( ^{1} \) can supply a gap for the HLA system and it is an approach to build distributed systems that deliver application functionality as services to end-user applications or to build other services. According to the characteristics of the HLA simulation system and the SOA system\( ^{1} \) many researches focus on the combination of HLA and SOA. In Refs.\( ^{1} \) 8\( ^{1} \) web enabling HLA is discussed and in Refs.\( ^{1} \) 9\( ^{1} \)\( ^{10} \) a framework of web service and HLA based complex product collaborative design is put forward.

In this paper we reference to the extensible modeling and simulation framework\( ^{1} \) XMSF\( ^{1} \) an extended HLA multilayer federation integration architecture\( ^{1} \) MLFIA\( ^{1} \) combined with SOA and HLA\( ^{1} \) SOHLA\( ^{1} \) is proposed\( ^{1} \). Firstly\( ^{1} \) we present the overall structure of MLFIA. Then\( ^{1} \) the detailed design and the implementation process of two major elements in MLFIA\( ^{1} \) resource management federation\( ^{1} \) RMF\( ^{1} \) and TH\( ^{1} \) RTI\( ^{1} \) an extensible HLA runtime infrastructure which can be used at Internet are discussed in detail.

1 Multilayer federation integration architecture

1.1 Structure of platform
A four-layer collaborative simulation platform architecture is shown in Fig. 1 which makes good use of current enterprise legacy model resources using RMF. At the same time\( ^{1} \) advanced simulation standard HLA and open web standard SOA are applied in the platform. The architecture contains four parts

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**Client Layer**: It is the environment for users. Users get access to simulation through browser or client software. In this layer, our work focuses on the federation portal, which is designed for users to access.

**Simulation federation pool layer**: Our platform supports multi-federation running simultaneously; all running simulation federations form a federation pool.

**RMF layer**: Resource includes domain models, knowledge, simulation federates and software resources. There are two main functions in RMF. One is resource management, the other is dynamic creation of simulation federation object model (FOM).

**Communication layer**: In this layer, TH RTI is designed according to the integration of HLA and SOA, using this RTI, multidisciplinary collaborative M&S can be carried out on Internet.

1.2 **Resource management federation**

Since the object model templates of HLA federations are not able to be updated during the running period, the research on a multi-federation system structure is carried out in which RMF is presented in the platform.

In the platform running period, RMF is always in existence. It controls creation of all the other federations. RMF solves two main problems in the collaborative platform: sharing resource management and the implementation of simulation FOM dynamic creation in which its principle is shown in Fig. 2.

The creation of simulation task comes down to the automatic construction of FOM and simulation object model(SOM) about simulation federation; the whole implementation construction of simulation task is shown as below:

1) **Resources discovery**: When a node that stores models joins RMF as a federate it should publish and subscribe some object classes and interaction classes; a resource list will be detected.

2) **Model assembly**: The simulation originator assembler interested models according to simulation task; it defines the mapping relationship among the models. The purpose of the assembly is to build SOM and FOM about the simulation federation. The kernel of the assembly is to adopt the base object model(BOM) which is defined by federation development and execution process in IEEE Std1516.3.

3) **Task creation**: Firstly, the core segment of federation execution data file FED is gained according to the above mapping relationship and FOM template; then the core segment is sent to every node via RTI services. Finally, a whole XML format FED file is made in node local side and simulation federation OMT dynamic deployment is accomplished.

4) **Simulation federation running**: The simulation originator sends a `start simulation task` interaction message and all other nodes start corresponding model resources. It should be emphasized that we adopt the daemon threads mechanism which not only makes models run independently with RMF but also be controlled by RMF.

It is a hierarchical structure between RMF and the application federations so we call it multilayer federation integration architecture.

2 **TH RTI—an extended HLA runtime infrastructure**

2.1 **Structure of TH RTI**

TH RTI is a web enabled RTI and developed by our teams; the structure of which is shown as Fig. 3.
TH _ RTI adopts a hibernacy structure model consisting of RTI executive process ] RtiExec ] federate executive process ] FedExec ] center RTI component ] CRC ] local RTI component ] LRC ] and web service RTI component ] WRC ] . The functions of RtiExec ] FedExec ] CRC and LRC are the same as the traditional HLA . WRC is a web service provider such as connection creation ] session management ] parameters configuration and etc . Remote web federates communicate with each other via WRC which interaction flow is shown as below . 1 ] WRC initialization starts the process in the server initializes the WRC module listens to the correlative port and waits for web federates to join in . 2 ] Web federate running after a web federate joins the federation ] RTI server should create and maintain an http session for it and the following communication should be exchanged in it . When a web federate exits the http session will be destroyed by the server . 3 ] Exchanged information web federates communicate with each other by a local agent ] SOHLA client ] and WRC .

2 . 2 Implementation of TH _ RTI

In HLA federates interact using RTI ambassador services and federate ambassador services call-backs which are defined in the interface specification . However in SOHLA federates interact indirectly via the proxy using web services . Therefore we must design web services for the two categories of HLA services . Meanwhile some auxiliary functions in HLA are also needed to be designed as web services .

Based on SOA after RTI is extended by the web services higher level of reusability and interoperability is realized mainly in three aspects .

1 ] Using web based message protocol SOAP / HTTP HLA - compliant federates can communicate with each other through RTI over WAN terminal applications can link to remote services and invoke remote methods easily and the affects on communication by firewalls are shielded .

2 ] Federates can reside as web services on WAN permitting an end - user to compose a simulation federation from a browser .

3 ] We can use a series of criterions in web services protocol stack to manage simulation resources and enhance the reusability of them .

TH _ RTI consists of two parts

1 ] RTI messaging proxy service Provide RTI message proxy service and make HLA services exist on the WAN as the form of Web Services .

2 ] Standard HLA services APIs Provide standard HLA services APIs as the form of new RTI library following the HLA interface specification and realize the criterions of interoperability and reusability that HLA demands . Fig .4 shows the implementation framework of TH _ RTI .
vices, the web services designed for federate ambassador services must be deployed at different client sides which will make it hard to design the proxy and to use TH - RTI. In this circumstance each client side must install a web services container. Therefore we use another method. When a proxy receives a request for a callback the proxy writes the information about the callback such as function name, content of parameters etc. to a sharable file. In addition we provide web services to parse the file. In client side users may create a timer to call the web services. When a callback is called by RTI the client side will get the information about the callback by using the web services and then call the callback provided by users.

Auxiliary web service TH - RTI also supports some auxiliary operations. Such as starting RTI before running a simulation users call the web service to start RTI determining whether RTI is running in RTI side before starting RTI users call the web service to determine whether RTI is running in RTI side or not and shutting down RTI after all simulations are finished users call the web service to shutdown RTI.

In the client side SOHLA RTI ambassador is designed at first. Though users can directly call web services in their simulation code it’s inconvenient for users to use TH - RTI. Therefore we wrap the web services provided by RTI ambassador web services and Auxiliary web services and provide standard HLA interface to users. It makes programming much easier. The standard APIs also enable users to be more consistent with their programming habits and simplify the conversion from HLA-based simulation to SOHLA-based simulation. Due to the characteristics of platform-independent and programming language-independent of web services different programming languages can be used to wrap these web services under different platforms to extend its application area. Secondly there is a BaseFedAmbassador class which implements NullFederateAmbassador. Users may override the callbacks according to their needs.

3 A case study of multiple unit

Multiple Unit MU is a type of railway vehicle groups a new China High-speed Railway of 16 Unit will be constructed in China. The development of MU has the character of multidiscipline techniques in various engineering domains. In order to consider the design problem globally at the early the design stage it is necessary to implement the collaboration simulation.

The design of MU multidisciplinary dynamics system depends on three domain models principally control model mechanical model and the hydraulic servo model. We have realized that the multidisciplinary modeling and simulation of MU development in our platform. The 3 domain modeling systems were implemented by Adams mechanical system Matlab control system and Hopsan hydraulic servo system. The interaction among various domain models based on SOHLA collaborative platform is shown in Fig.5.

As mentioned in the above second section there are mainly four steps for the MU collaborative simulation. The first step is resources discovery in which a user can find the models need though our federation portal as shown in Fig.6 The second step is model assembly in which a user can also do it with a mouse in a web browser and a graphical interface is given as shown in Fig.7 and it makes FOM mapping very easily The third step is the simulation task creation in which a XML format FED file would be deployed in every simulation node and the MU simulation federation physical structure is shown as Fig.8 The last step is the MU simulation federation running a viewer is given to monitor the simulation process.
4 Conclusions

Some remarkable characteristics and advantages of MLFIA are shown as follows:

1. RMF changes the original flat structure of multiple simulation federations to hierarchical federations and realizes the creation and execution of multiple simulation federation tasks in the frame of HLA. RMF makes the platform keep highly consistency with the HLA standard and improves the reuse efficiency of models and supports the multi-federation task simulation running.

2. TH _ RTI extends the abilities of traditional HLA runtime infrastructure which not only can be used in local area network but also can be used in Internet. This characteristic supports better interoperability among heterogeneous simulations and better reusability of legacy models and simulations.

Our future work is concerned with the implementation collaborative simulation algorithm.

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