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Integrated Simulation Framework based on Data Interaction

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Abstract: Co-simulation between HILS and distribute Mathematical Simulation System （DMSS）is the difficulty of collaborative simulation technology development. This paper proposes a simulation framework based on data's time attribute to classify original simulation system's simulation module of the integrated framework hardware-in-loop simulation system (HILS) and DMSS. Based on the mathematical description of integrated framework a layered analysis of time synchronization strategies and simulation management mechanism are introduced and the integrated framework is constructed based on module layer unit (MLU). Finally, this paper introduces the use of the integrated framework to construct the integrated simulation system composed with DMSS and RF-simulation system.

Keywords: integrated simulation system, integrated framework, HILS, distribute Mathematical Simulation System, module layer unit, RF-simulation system

1 Introduction

With the development of simulation technology, its application is spreading rapidly，some simulation systems have been developed to meet different application requirements. Scale complex system has been simulated by Distribute Mathematical Simulation System（DMSS）by the widely use of HLA frame structure [1]. Radio frequency (RF) simulation exploits the nature of RF circuits to overcome bottlenecks that prevents the use of general purpose simulation [2]. It is a large and complex HILS which is designed to realistically recover RF target and the environment. How to take advantage of the ability which is combined with distributed Mathematical Simulation System and RF simulation is a tendency of simulation technology. In order to cater to this trend，these two types of heterogeneous simulation system should be integrated. Because of heterogeneity of these two simulations in time management and simulation management, a framework should be researched to achieve the goal of these systems' integration. Some research institutes and universities had made some efforts to the simulation system integration, but these researches can hardly solve the problems completely which appears in the process of system integration [3].

This article proposes the integrated framework based on the data exchange after the study of time synchronization, data exchange and simulation management between DMSS and RF Simulation system. Then, a simulation integration framework based on data exchange is built and described. In the last part of this paper, an application of the framework is introduced to test and verify its feasibility.

2 Integrated simulation system integration framework of MLU

The framework structure is shown as Figure 1. In figure structure, the framework is composed by simulation management module, time management module and MLU simulation management module. Simulation management is responsible for managing every MLU simulation management module and MLU simulation management is used to manage MLU 's internal simulation process of simulation. The time

calibration and time synchronization of integrated simulation system are realized by time management module.

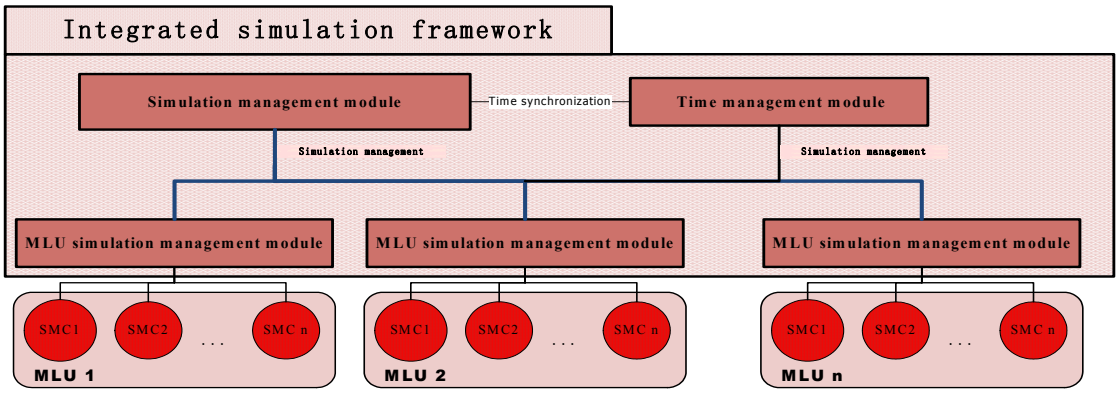


Figure 1 Integrated framework based on MLU

2.1 MUL in integrated framework

MUL is a basic unit in the integrated framework. The framework can transmit the data between OSSs through the unified management of MLU. The structure of MLU can be shown as Figure 2. It is composed of simulation module cluster (SMC) consisted of integrated simulation system's module which has the same real-time attribute to interface of SMC and interface of MLU. The duties of the SMC's interface are to exchange the data between SMSs belonging to different OSSs, and the interface of MLU can exchange the data between various MLUs. Because of the same time attribute of SMC belonging to one MLU, it would be easy to realize the data interaction between SMCs.

In integrated simulation systems, the data interaction of different OSSs is the data exchange between various simulation modules ultimately. By the way of the framework based on MLU, no- real-time DMSS can be divided into several MLUs which have different time attributes. If this no-real-time module has no data interaction with other real-time simulation systems, the DMSS can be integrated with the real-time HILS.

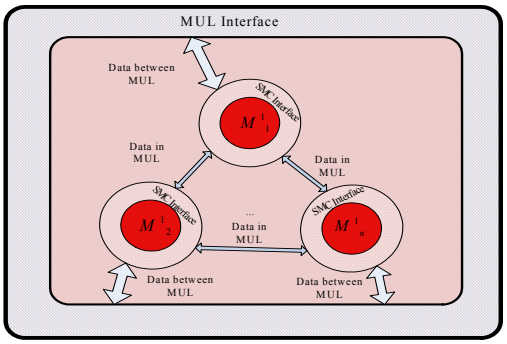


Figure 2 Structure of MLU

2.2 Time synchronization mechanism of framework

In the framework based on MLU, time synchronization has three levels：synchronization between MLUs，synchronization between SMCs and synchronization between modules in OSS. Time synchronization process can be viewed in Figure 3.

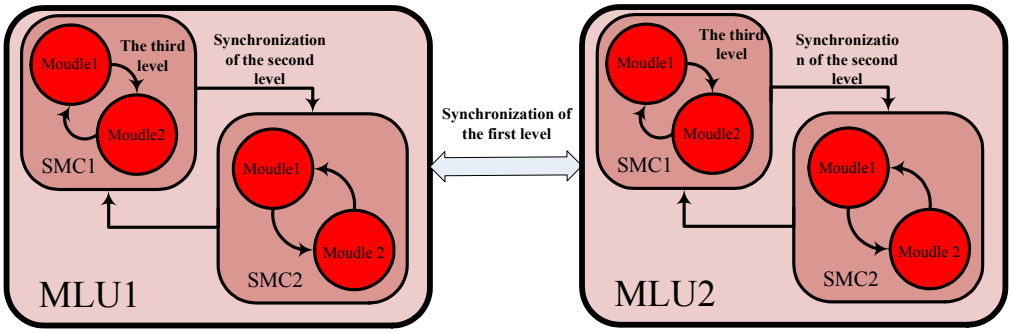


Figure 3 Time synchronization in integrated framework

- Synchronization between modules in OSS：Because the framework does not break the time synchronization mechanism of OSS，synchronization between modules in OSS can inherit the mechanism of OSS.
- Synchronization between SMCs：Since the SMCs have formed various OSS with different time synchronization mechanism, they need the time synchronization to make the SMCs have the only timeline.
- Synchronization between MLUs：With the same purpose of synchronization between SMCs, the synchronization between MLUs is to meet the time logical sequence of interaction data from different MLUs.

3 The application used by the integrated framework

Two distributed simulation systems in our lab need to be integrated for co-simulation. One is DMSS which is created by HLA and it has no-real-time attribute. Another is RF simulation which has demanding real-time attribute. By using the framework being introduced above, we create the integrated simulation system composed by DMSS and RF simulation system. The integrated simulation structure is shown as

Figure 4. The module time attribute in this integrated simulation system has four real-time levels：No-real-time attribute, weak real-time attribute, real-time attribute and demanding real-time attribute. Therefore the integrated simulation system is composed by four MLUs.

Referring to the time synchronization mechanism of framework, the integrated simulation uses the type of master-slave time synchronization to synchronize the module's timeline. There are one master synchronization source only and two slave synchronization sources. The master synchronization source is a time crystal derived from RF simulation system's timer, in which the timeline of RF simulation system's module is synchronized. Slave time synchronization source 1 is a time server in real-time MLU and slave time synchronization source 2 is an attackers' interface module which is a constrained federate in weak real-time MLU. Synchronization source 1 is the master synchronization source for synchronization source 2. As the time synchronization begins, the master synchronization source supplies the plus single of time synchronization with the frequency of 100k. Then slave time synchronization source 1 receives the single by time card to calibrate it's own timer which is to synchronize the modules of MLU and source 2 by the way of NTP. As slave source 2 is a constrained federate in weak real-time MLU, it can control other federate in the MLU by the time management mechanism of HLA. As a consequence, the integrated simulation system is capable of fulfilling time synchronization function with its three synchronization sources.

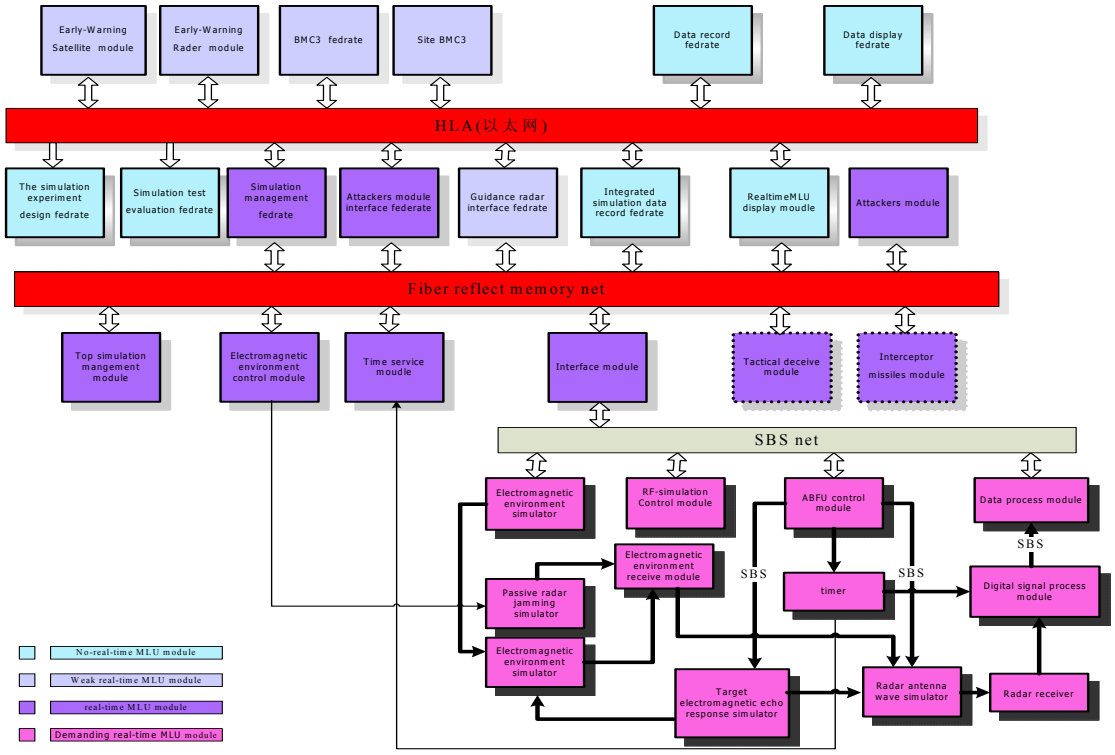
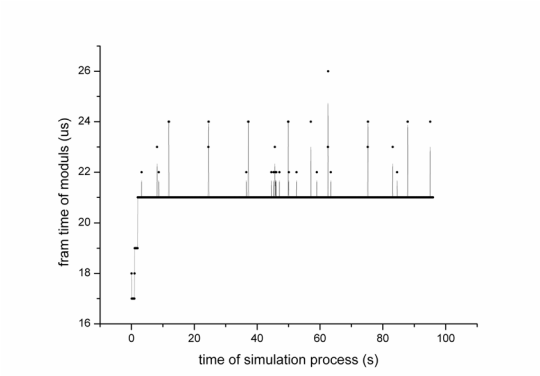


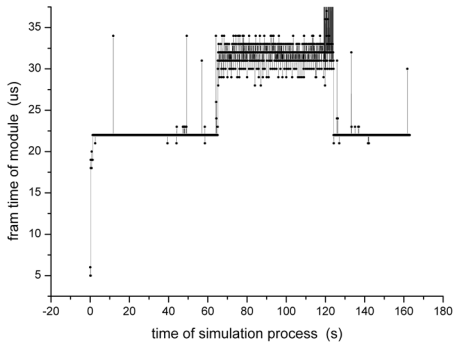
Figure 4 Integrated Simulation System structure

4 Real-time test of integrated simulation system

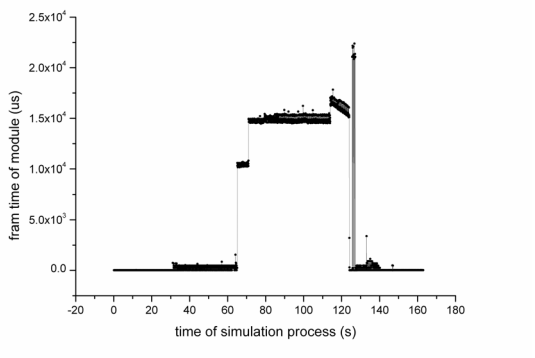
Since the RF simulation in our lab is a real-time simulation, the real time test is necessary to be conducted in the integrated simulation systems in which one of the OSS is RF simulation system. In the integrated simulation system, the demanding real-time MLU is composed by RF-simulation and its simulation step is 5ms. The real-time MLU is newly constructed whose step is 50ms and the DMSS is divided into weak real-time MLU whose simulation step is 100ms and no real-time MLU. This test emphasis newly constructed MLU which is a real-time MLU. The test related graph is shown as Graph 5 to Graph8.



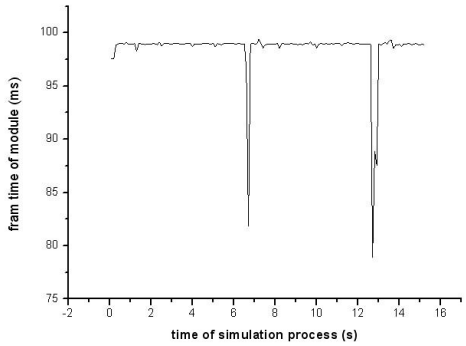
Graph 5 Tactical deceive module



Graph 6 Attackers module



Graph 7 Interceptor missiles module



Graph 8 Interface federate of attackers module

From the figure above, since all frame time of modules in real-time MLU is less than 50 ms and the DMSS's frame time is below 100ms, we can draw the conclusion that the real-time MLU does have real-time attribute.

5 Conclusion

In those integrated simulation systems which contain both HILS and DMSS, the real-time difference between HILS and DMSS is the core issue in constructing integrated simulation system. Different simulation systems have different time management ways, simulation management modes and system construction forms. However, different simulation systems have one thing in common, that is they all interact data according to a certain logic order. Therefore, when facing a simulation system which has much real-time difference such as HILS and DMSS, an integrated simulation framework based on data interaction is able to be constructed by starting from the similarities of simulation systems.

Integrating those existing simulation systems to an integrated simulation system to achieve the new simulation application requirements through collaborative simulation between those existing systems is a branch of current simulation technology development. On the basis of data interaction similarity of different simulation systems, this paper constructed a MLU-based integrated framework during the process of DMSS and RFS integration at our lab and then described its working process through constructing mathematical simulation system. Finally it verified through real-time test that implementing the integration framework to integrate the existing simulation systems in lab was successful.

6 Reference

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