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A STUDY ON SUPPORT SYSTEM FOR DISTRIBUTED SIMULATION SYSTEM OF MANUFACTURING SYSTEMS USING HLA

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Abstract: In this paper, we firstly describe outlines of the developed distributed simulation system using HLA and the developed synchronization method in the past. We clarify requirement contrivances of the user support system. We explain requirement functions of the user support system that is premised on using the developed distributed simulation system and the developed synchronization method. We propose and develop the user support system. The case study was then carried out to evaluate the performance of the cooperative work.

Key words: HLA, distributed simulation, manufacturing system, user support system, XML

1. INTRODUCTION

A simulator plays an important role in designing new manufacturing systems [1][2][3][4]. As manufacturing systems are being created on larger and more complicated scales than ever before, it is increasingly necessary to design a manufacturing system with several persons concurrently. Then each manufacturing system designer uses manufacturing system simulator. At present, it is very difficult to combine different models which are made by different simulators because there are no standard descriptions for simulation models and a standard language for simulation programs has not been developed. In order to evaluate the whole system, a distributed simulation technology begins to attract industries. The distributed simulation technology is defined as executing a simulation while connecting and synchronizing several different simulators [5].

Concerning the distributed simulation technology, there are many research papers in academe [5][6]. But there are a few cases where industries have used the ideas presented in those papers. In order to use the distributed simulation technology in actual designs of manufacturing systems, it was necessary to develop the following items.

1. A distributed simulation system which is easy to use in various industries using commercial based manufacturing system simulators.
2. A method to synchronize commercial based manufacturing system simulators using characteristics of manufacturing system designs.
3. A user support system to define several relationships such as network relationships, simulation model relationships and so on using visual user interfaces while consistently keeping defined parameters along a definition procedure and to execute a distributed simulation remotely.

We have already proposed and developed the distributed simulation system using High Level Architecture (HLA) and the developed synchronization method [1][2][3][4]. Therefore we focus on the user support system.

In this paper, we firstly describe outlines of the developed distributed simulation system and the developed synchronization method in the past. We clarify requirement contrivances of the user support system. We explain requirement functions of the user support system that is premised on using the developed distributed simulation system and the developed synchronization method. We propose and develop the user support system. The case study was then carried out to evaluate the performance of the cooperative work.

2. DISTRIBUTED SIMULATION IN ACTUAL DESIGNS OF MANUFACTURING SYSTEMS

2.1 Manufacturing adapter of distributed simulation systems using HLA

HLA is only one standard for the distributed simulation system architecture as IEEE 1516 [7]. Currently there are several commercial based HLA Runtime Infrastructures (HLA/RTIs) which provide many kinds of services which are defined in IEEE1516.1 interface specifications [7].

However in order to use the commercial based HLA/RTIs for distributed simulations of manufacturing systems, the manufacturing designer needed to implement interface modules combing program methods based on the specifications by himself. Therefore it was difficult for the designer to use HLA.

In order to solve the problem, an adapter intermediately between manufacturing simulators and HLA/RTI has been developed [1][2]. This adapter is called a manufacturing adapter. Figure 1 shows the proposed manufacturing adapter.

Concerning communication between the manufacturing adapter and the simulators, XML format messages have been developed [1][2]. Using the manufacturing adapter, the simulator can access the services of HLA/RTI by only sending the XML format messages without implementing any program methods.

We have also proposed a Relational Data Definition (RDD) file which defines exchanged message contents between the simulators [1][2]. We have developed XML format definitions in the RDD file. The manufacturing adapter has been developed to get the message exchange services by reading parameters of the RDD file when the manufacturing adapter starts. The contents of the RDD file describe exchanged message contents. Therefore the RDD file is important to connect with simulation models.

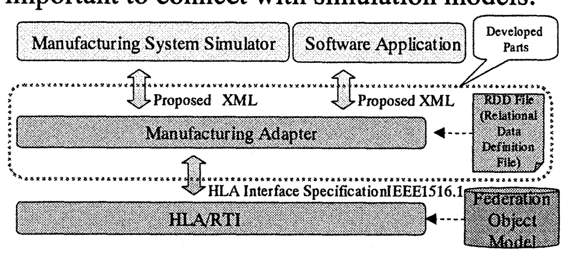

Figure 1. Outline of the manufacturing adapter.

2.2 Synchronization method for distributed manufacturing simulation systems

In actual manufacturing systems, relationships between the subsystem and the other subsystems are defined as input and output of material flow. Storage function units such as warehouses and buffers are usually located intermediately between the input part of a subsystem and the output part of other subsystems. The model of the each subsystem on the suitable simulator has an input part and an output part of the material flow. Therefore a system model can be made by connecting the input part of the subsystem model and the output part of the other subsystem models. To connect different simulators, the focus of our study has been on the storage function units as association points between the subsystems. In simulators used in this study, the storage function units are defined as storage models.

Figure 2 shows a fundamental structure to connect two different simulators by using the storage model. Each subsystem is modeled by different simulators (A and B). The warehouse is modeled as a storage model in each simulator. The simulators are synchronized by the proposed synchronization method using conditions of amounts of stock in the storage models [3][4]. This method can be adapted for synchronizing distributed simulation clocks without the rollback function which is to return the simulation clock to passed time to synchronize events among the simulations [3][4]. This method is necessary for actual designs of manufacturing systems because commercial based manufacturing system simulators do not have the rollback function.

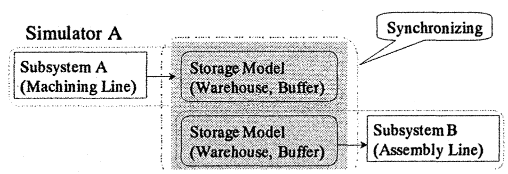

Figure 2. Outline of the proposed synchronization method.

2.3 User support system for distributed manufacturing simulation systems

In a definition procedure to execute the distributed simulation system, the manufacturing system designer needs to define many parameters. If only a definition contradiction occurs, the designer does not have inconsistent simulation results, but also loses a lot of time to detect the definition contradiction. Therefore it is necessary to prevent careless mistakes through the definition procedure such as definition contradicts of messages among the simulators, definition omissions, double definitions and so on. In order to prevent careless mistakes through the definition procedure, it is necessary to support the definition procedure consistently while storing and reusing the definition parameters.

Particularly in a case that a relationship among a message sender and message receivers is in the ration of one to many and also there are many kinds of messages such as very large manufacturing systems, there are probabilities to make definition mistakes for the relationships because the relationships become complicated. In such a case, it is effective to use a visual user interface (VUI) which provides modeling functions to define and express the relationships.

On the other hand, in a case that each simulator is located away from the other simulators, it is necessary for only a manufacturing system designer to initiate and execute the distributed simulation system remotely.

In this paper, we propose a user support system to solve the above issues. The user support system is premised on using the developed distributed simulation system (op. cit. chapter 2 section 1) and the developed synchronization method (op. cit. chapter 2 section 2). Figure 3 shows an outline of the user support system and relationships among the user support system, the distributed simulation system, and the synchronization method.

The user support system includes the following contrivances.

1. The user support system has a contrivance to support the definition procedure consistently while storing and reusing the definition parameters.
2. The user support system has a contrivance to provide visual user interfaces (VUI). For example, a visual interface provides modeling functions to make and express message relationships among a message sender and message receivers.
3. The user support system has a contrivance for only a manufacturing system designer to execute the distributed simulation remotely.

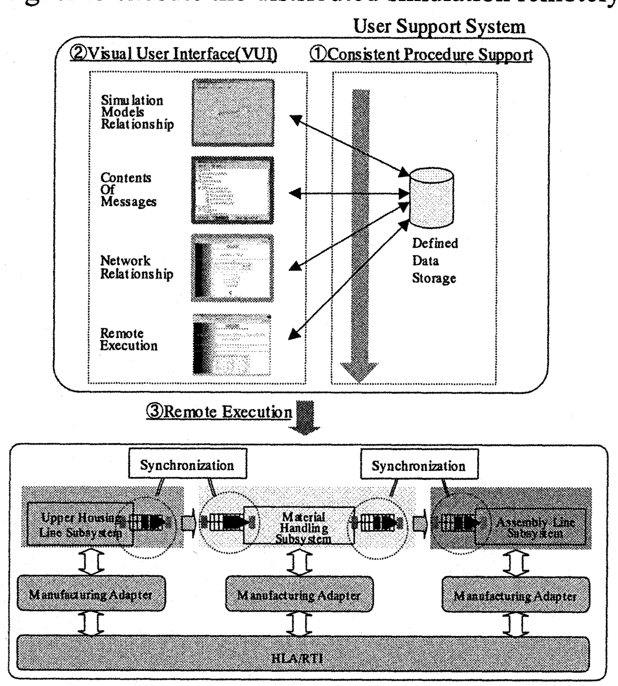

Figure 3. Outline of user support system.

3. REQUIREMENT FUNCTIONS OF USER SUPPORT SYSTEM

We analyzed procedures of the definitions and execution for the distributed simulation system using the synchronization method. We clarified requirements for the user support system. We classify the requirements into seven functions for user support system as a project management function, a modeling function, a network definition function, a RDD file generation function, a FOM file generation function, a file transfer function, and a remote execution function. Figure 4 shows an outline of the functions of the user support system.

Firstly, main roles of the project management function are to declare a project as the first step in the definition procedure and to manage storing and reusing the defined parameters by the designer.

Secondly, the modeling function includes three functions. At first, in order to define the storage models as the association points among the simulation models, the modeling function provides a function to define a relationship between a name of a federate which means a simulator in HLA and a name of the storage model which is modeled on the federate. The modeling function also provides a function to make message relationships between a storage model as a message sender and the other storage models as message receivers. Using these two functions, it is possible to express the message relationships among the federates visually by arrows from the federate as the message sender to the federates as the message receiver. The modeling function provides such a visual expression function.

Thirdly, main roles of the network definition function are to define a network environment of each federate and to define parameters of the socket communication between the manufacturing adapter of each federate and HLA/RTI. In this function, the designer can reuse data that have been defined in the modeling function by the project management function.

Fourthly, the RDD file generation function generates data of each RDD file using the defined parameters in the modeling function and the network definition function. Contents of the RDD file are formatted by XML. The RDD file includes the defined messages contents, the defined network environment, the defined parameters of the socket communication and so on using data of the modeling function and the network definition function.

Fifthly, the FOM file generation function generates data of the FOM file using all of the definition messages in the modeling function.

Sixthly, the file transfer function includes two functions. At first, the file transfer function provides a function to define exact locations where the RDD files and the FOM file are located in personal computers (PCs). The file transfer function provides a function to send the RDD files and the FOM file to the defined locations.

Finally, the remote execution function provides a communication function of a client-server type between a client side PC which sends indications to initiate and execute the federate and a server side PC which receive and serve the indications to initiate and execute the federate.

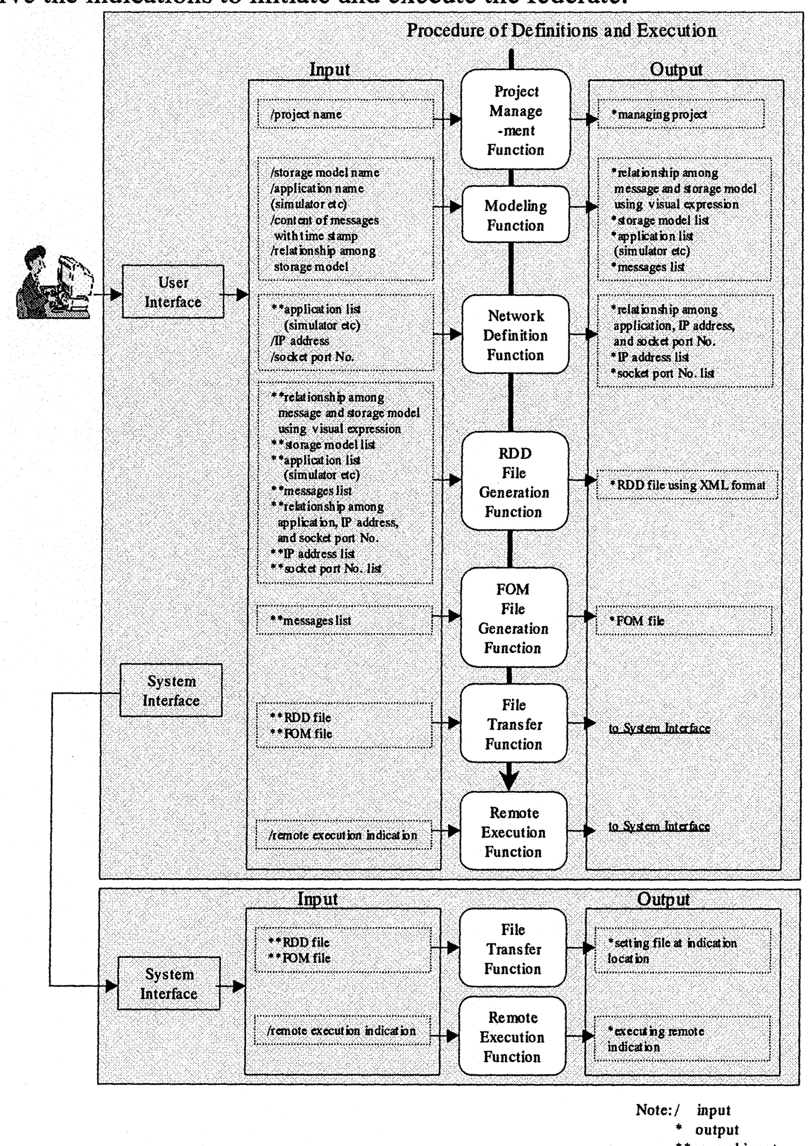

Figure 4. Outline of functions of user support system.

4. DEVELOPMENT OF USER SUPPORT SYSTEM

In order to implement classified seven functions, we propose and develop Distributed Simulation Modeling and Execution (DISMO) as the user support system. In DISMO, the Web server technology, the servlet technology, and the Java program technology are used for the designer to get services of seven functions using an Internet browser. Apache version 3.20 as the Web server and Tomcat version 3.1 as the servlet are used in DISMO.

DISMO consists of a DISMO Design Server (DISMO-DS) and DISMO Simulation Servers (DISMO-SS). DISMO-DS is a core server to support the designer through the Internet or Intranet technology. DISMO-DS provides seven requirement functions. DISMO-SS is a serve where an application such as the manufacturing system simulator is implemented. DISMO-SS provides the file transfer function and the remote execution function.

5. CASE STUDY

The developed user support system is confirmed using a case to evaluate a hypothetical manufacturing system which produces motors. Figure 5 shows a layout of the manufacturing system and relationships among simulation model using the storage models. With this manufacturing system, it is assumed that three companies design the manufacturing system separately and concurrently. Company B designs the upper housing line subsystem. Company C designs the assembly line subsystem. Company A designs the other subsystems which include the storage and the material handing subsystem. In this case study, three manufacturing system simulators as QUEST [8], eMPlant [9], and GAROPS [10] are used.

Three simulators are located on three places as Tokyo Metropolitan, Saitama Prefecture, and Aichi Prefecture. It is technically possible to connect three simulators using Internet. However this is not reality because of security problems. Therefore we chose Intranet to connect the simulators. Three simulators are connected by Integrated Service Digital Network (ISDN) using Remote Access Server (RAS).

At first, this case study was registered as a new project in DISMO. The designer defined message contents and the relationships between the storage models using the VUIs which are provided in the modeling function. Figure 6 shows the definition of the message contents using the VUI. Figure 7 shows the message relationships using the VUI by arrows from the federate as the message sender to the federates as the message receiver. After the modeling function, the network parameters for each manufacture adapter were defined. After these definitions were finished, the RDD files and the

FOM file were generated by DISMO. These files were translated to the defined locations. Then the designer indicated to initiate and execute the distributed simulation system. After the procedure to define and execute the distributed simulation, we confirmed that the distributed simulation system using the synchronization method could be executed exactly. Therefore the case study of the developed user support system was carried out to evaluate the performance of the cooperative work.

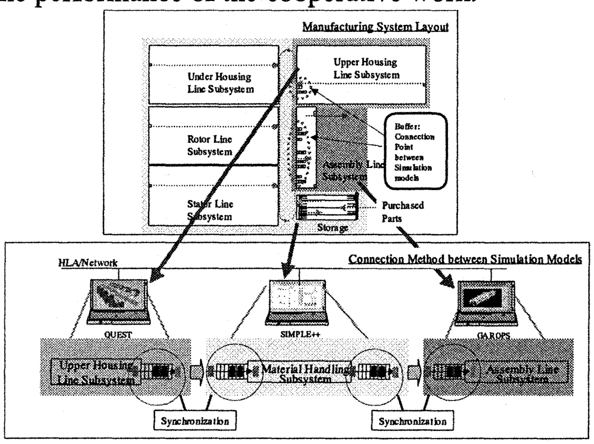

Figure 5. Layout and relationships among simulation models.

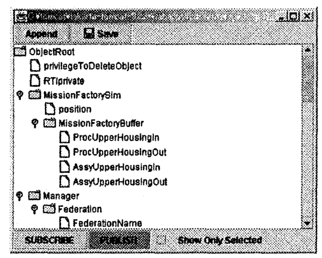

Figure 6. Definition of message contents by DISMO.

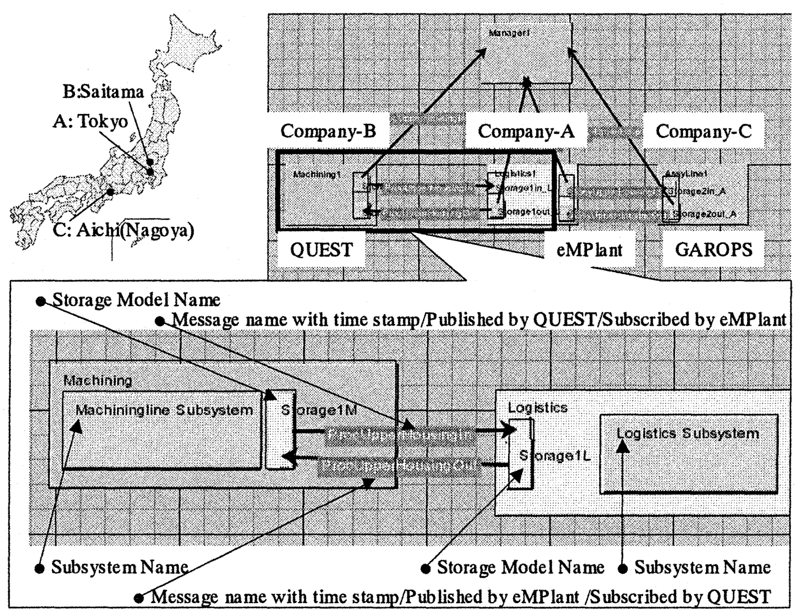

Figure 7. Definition of message relationships visually by arrows using DISMO.

6. CONCLUSION

In this paper, we firstly described outlines of the developed distributed simulation system using HLA and the developed synchronization method in the past. We clarified requirement contrivances of the user support system. We explained requirement functions of the user support system that is premised on using the developed distributed simulation system and the developed synchronization method. We proposed and developed the user support system. The case study was then carried out to evaluate the performance of the cooperative work.

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