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METHOD AND TOOL FOR DESIGN PROCESS NAVIGATION AND AUTOMATIC GENERATION OF SIMULATION MODELS FOR MANUFACTURING SYSTEMS

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Abstract: Manufacturing system designers should concentrate on designing and planning manufacturing systems instead of spending their efforts on creating the simulation models to verify the design. This paper proposes a method and its tool to navigate the designers through the engineering process and generate the simulation model automatically from the design results. The design agent also supports collaborative design projects among different companies or divisions with distributed engineering and distributed simulation techniques. The idea was implemented and applied to a factory planning process.

Key words: Manufacturing System, Concurrent Engineering, Simulation, Design Agent

1. INTRODUCTION

Global competition forces industrial companies to reduce the cost and time needed for the development of new manufacturing systems. To achieve this goal, manufacturing system simulators have been employed. However, manufacturing system designers should be concentrating on designing and planning the systems instead of spending their efforts on creating the simulation models in order to verify the results. The more time designers need to build simulation models, the less time they have to develop the manufacturing system. On the other hand, if consultants, vendors or software engineers build and verify simulation models for the manufacturing system

engineers, many problems such as incorrect input data, misunderstanding of the model and misleading of the decision from the results may occur.

To overcome the problem, this paper proposes a method and its tool, referred to as a design agent system [1][2], to navigate the designers through the engineering process and generate the simulation model automatically from the design results to evaluate the system performance. Data exchange from CAD systems to simulators was considered [3]. This paper deals with not only the exchange but also the building of manufacturing system models. The Product Process Resource (PPR) [4] approach is also a promising approach to build manufacturing system models. Though it is a supporting tool to manage a large amount of data in a standard engineering process and collect the appropriate data for the simulation, the approach in this paper focuses on modelling the engineering process linked to the system data and directly generates the simulation model from the design specifications.

The design agent supports not only a designer in a company or division but also collaborative design projects among different companies or divisions. The manufacturing system model is built concurrently and translated into a simulation model or separate simulation models if different simulators are employed. In the latter case, the models are simulated in a distributed environment using the High Level Architecture (HLA) [5]. The proposal has been discussed under Intelligent Manufacturing Systems (IMS) Modelling and Simulation Environments for Design, Planning and Operation of Globally Distributed Enterprises (MISSION) international project including institutes and companies from Japan, Europe and USA [6]. The design agent system was applied to a factory planning process involving four companies to develop a factory including assembly lines, processing lines and a transportation system.

2. DESIGN PROCESS NAVIGATION

The structure of the design agent system for navigating the design process to build manufacturing systems is shown in Figure 1. It has two categories of agents: client agents which interact with engineers and server agents which manage data base for the agent system (referred to as Design Agent Database), deal with communications among client agents and provide mobile agents such as collecting data in a distributed network. The client agents are downloaded as JAVA applets. The Design Agent Database includes Project Case Library to accumulate and reuse project cases and Manufacturing System Component Library (referred to as MS Component Library) to define the structure of components in manufacturing systems such as enterprise, factory, production line, cell and equipment in an object-oriented manner. The MS Component Library provides unique names,

standard values and design rules of design parameters in each component. All agents communicate through the Manufacturing System Engineering (MSE) Network such as CORBA and DCOM, distinguishing the distributed simulation network described later.

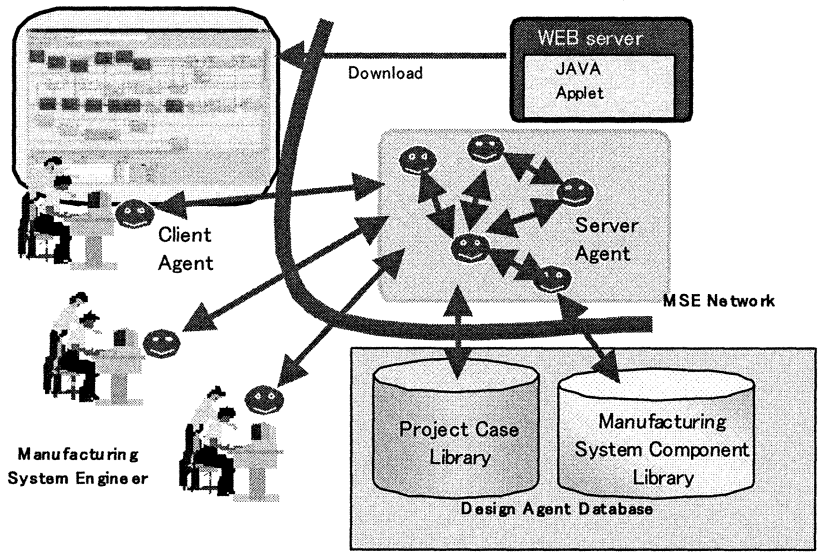

Figure 1. Architecture of the design agent system.

Design Process Agent is a client agent that has a central role to navigate engineers in the design of manufacturing systems as shown in Figure 2. At first, engineers give the requirements of a manufacturing system to the Design Process Agent. The agent helps the engineers search for an appropriate project case in the Project Case Library, and routinely support them to build the system model by showing a list of appropriate components in the MS Component Library. As the design process improves from an initial rough-cut model to a detailed one, the Design Process Agent creates the design process and the manufacturing system model that consists of the manufacturing process, the system components such as facilities and workers and the layout.

A requirement, design process, layout and manufacturing system model are described in eXtensible Markup Language (XML) so that software vendors can easily develop the interface to the design agent system.

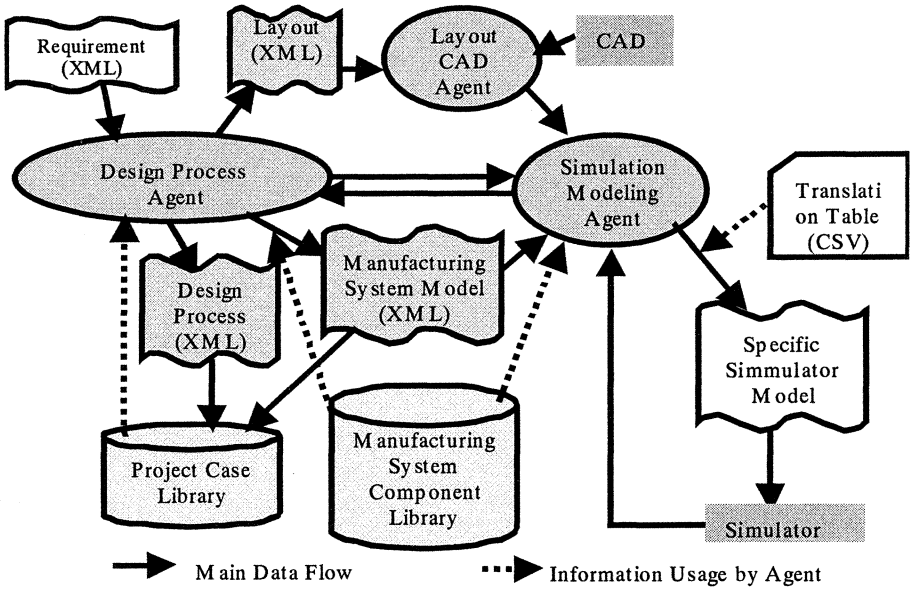

Figure 2. Client agents and their roles

3. AUTOMATIC GENERATION OF SIMULATION MODELS

Tool Agents are client agents that support engineers to use engineering tools. Simulation Modeling and Layout CAD Agents in Figure 2 are the Tool Agents. The Simulation Modeling Agent has the following functions:

- Know what simulation packages are available and how to select them [2].
- Know how to translate a manufacturing system model created by the Design Process Agent into specific simulation models.
- Know how to get simulation results from simulators and give the results to the Design Process Agent.

The agent translates the system model to a model for a simulator to evaluate or animate the model. The Translation Table in Figure 2 is defined to translate the attributes of a class in the MS Component Library to the corresponding attributes in the factory facilities used in specific simulators. For example, the class "storage" in the MS Component Library may be called "Buffer" in simulator A, and "Accumulator" in simulator B. There are specific parameters such as a facility color and simulation length in

simulation study. If those parameters are not found in the MS Component Library, the Simulation Modeling Agent asks users to provide appropriate parameters. The Translation Table is described in Comma Separated Values (CSV) format so that engineers can easily change the table. The Simulation Modeling Agent provides the Design Process Agent with the simulation results such as the system performance and the utility rates of machines.

A simulator can be employed before or after a CAD system as shown in Figure 3 because the simulation model usually serves for both evaluation and animation. The design agent system provides an initial layout file for a CAD system and the Simulation Modeling Agent can use either a layout from the manufacturing system model to evaluate the system performance or a layout from a CAD system to animate with higher fidelity. Because CAD systems do not usually output XML files, the Layout CAD Agent is employed to translate the layout data for CAD systems into the XML files.

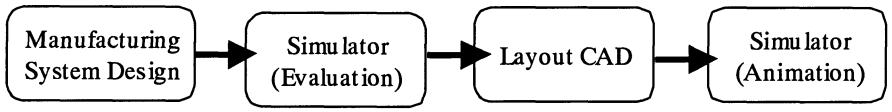

Figure 3. Roles of CAD and simulator

4. IMPLEMENTATION OF DESIGN AGENT SYSTEM

The design agent system was implemented by using JAVA language. We designed a virtual factory that produced motors for automobiles and consisted of processing lines, assembly lines and a logistic system where automated guided vehicles transported parts between the production lines and a storage system. Figure 4 shows the main procedure used with the agent system.

The requirements include a design order sheet including a rough specification such as production volume and work schedule, product structure usually given in a CAD system, and an initial layout for information. The manufacturing model of an appropriate case is shown up as a template to the engineer in three views: the design process, the manufacturing process and the layout. The Design Process Agent navigates engineers to change the design process that in turn produces a new manufacturing process and a new layout. The design parameters of the facilities are provided in the design process. A simulator [7] was employed

to evaluate the system performance because it provides a language for easy development of the interface to the Translation Table.

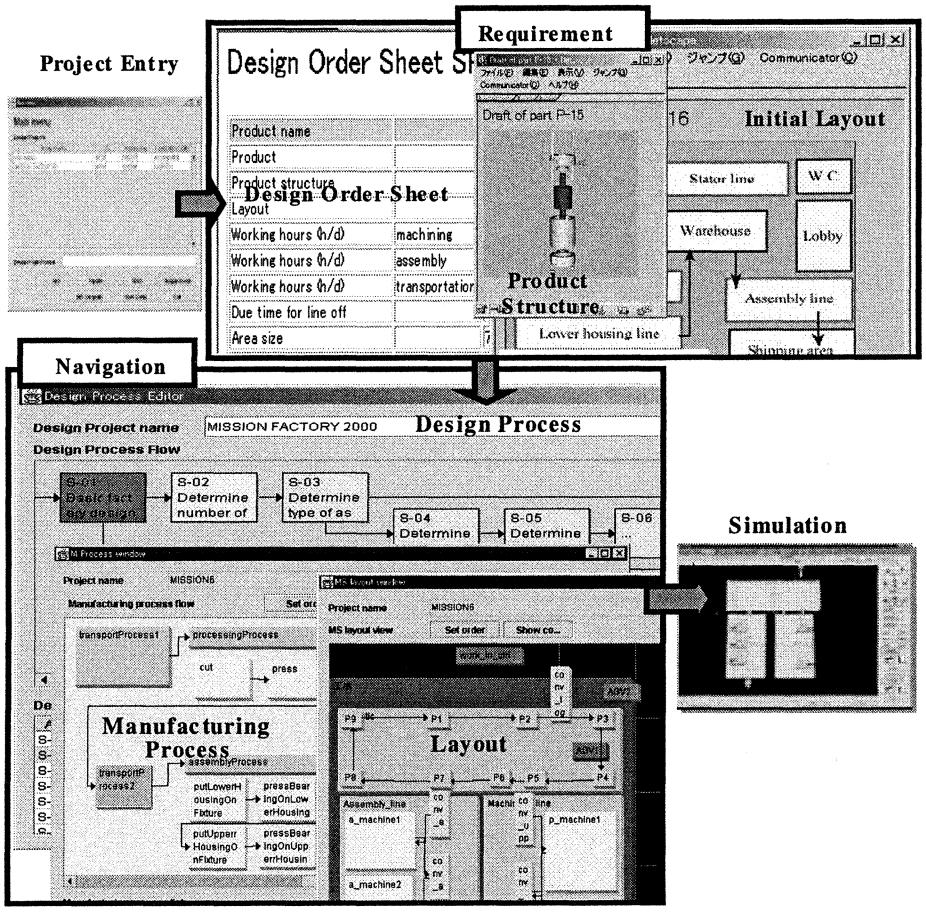

Figure 4. Main procedure of the design agent system.

5. DISTRIBUTED ENGINEERING AND DISTRIBUTED SIMULATION

The design agent system can be employed in collaborative projects to design not only a manufacturing system but also a manufacturing enterprise including sales, logistics and planning for manufacturing in a globally distributed enterprise. The design agent system can also be employed to design a virtual enterprise in which several companies do business together. As a result of distributed engineering, a distributed simulation is desired to evaluate or animate the entire model [8]. Although techniques of distributed

simulation have been studied [5], the combination of the distributed engineering and distributed simulation has not yet been studied in depth. In this solution, the MS Component Library has an important role to integrate the manufacturing system models into the simulation model correctly.

Four companies in Japan collaborated in a study to build the virtual factory described in Section 3. In this virtual project, the owner company gave three companies the requirements to build assembly lines, processing lines and a transportation system respectively as shown in Figure 5. The architecture of the distributed simulation should have the capability to develop a control policy to proceed simulation time. The proposed system is based on the HLA. The data model communicated among simulators is based on the MS Component Library but data specific to the distributed simulation such as a time stamp, a source ID and a destination ID are added. The Distributed Simulation Modeling Agent is proposed to generate the data model in the Federation Execution Data (FED) file. The HLA adapter has an interface to the individual simulators and manages the simulation data under the HLA. The simulators have the function to pause a simulation at a certain time in order to simultaneously proceed with other simulators. The HLA manager monitors the HLA adapters and gives the feedback of the results to the Design Process Agent. The virtual collaboration project was successfully studied by the cooperation of the four companies [2].

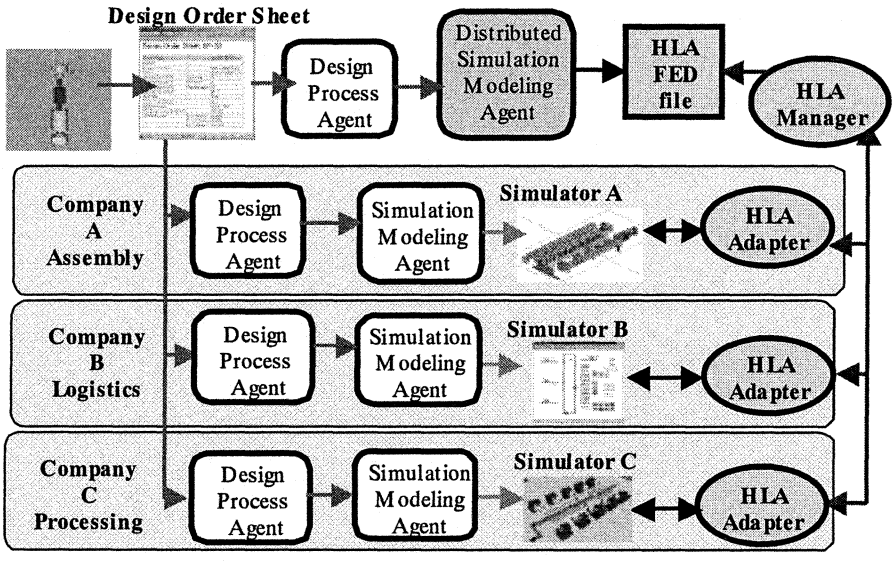

Figure 5. Distribution engineering and simulation

6. CONCLUSION

The paper proposes the method and its tool to navigate engineers to develop manufacturing systems. The manufacturing system models from the design system are translated automatically to the simulation models to evaluate the performance or animate. The combination of distributed engineering and distributed simulation is also proposed for global enterprises, demonstrating that the design agent system can be applied to the enterprise planning beyond manufacturing systems.

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