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Development of a multi-agent-based distributed simulation platform for semiconductor manufacturing

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ABSTRACT

Since the semiconductor manufacturing system is a large-scale complex system, it is difficult to solve complex problems in semiconductor manufacturing by the mathematical modeling method. This paper presents a multi-agent-based distributed simulation platform to support the extremely complex semiconductor manufacturing analysis. A multi-agent-based distributed simulation platform framework and a multi-agent collaborative control model are proposed to provide a flexible infrastructure and a multi-agent coordination mechanism in distributed environment for semiconductor manufacturing simulation. A multi-agent time synchronization model for distributed simulation is designed to keep events in the correct logical time order in simulation and steps of time synchronization are given. An interaction model and message formats are presented to describe how agents communicate with each other in simulation. The platform development and the design of graphical user interface are also exploited in this paper. Finally, evaluation of this multi-agent-based platform was illustrated with a case study. It indicates that the platform is effective in modeling and simulating the complex semiconductor manufacturing and provides the insights about how to improve the semiconductor manufacturing process with well targeted measures.

1. Introduction

Semiconductor manufacturing includes four phases: wafer fabrication, wafer probe, assembly and final test. The first two phases are called front-end production, and the last two are named back-end production (Uzsoy, Lee, & Martin-Vega, 1992). Wafer fabrication includes many processes, such as cleaning, oxidation, chemical vapor deposition, lithography, etching, ion implantation and so on. Wafer fabrication process is the most capital intensive and complex of the four phases (Geng, Jiang, & Chen, 2009; Zhang, Jiang, & Guo, 2009). In the phase of wafer probe, the circuits in the wafers are tested for functionality using electrical probes. The wafers are then cut into individual circuits called die, and the defective circuits are discarded. In the next phase, the dies are connected to leads and placed in ceramic or plastic shells to protect them from the environment. In the final phase, the packaged integrated circuits are sent for final functional test for customer specifications. Semiconductor manufacturing has the following characteristics: a large-scale complex system (Lee, Jiang, & Liu, 2009; Zhang et al., 2009), reentrant process flow (Lee et al., 2009; Vargas-Villamil, Rivera, & Kempf, 2003), various types of products (Mok, 2009; Li & Huang, 2009), and a large number of processing machines (Li & Huang, 2009). Therefore, these characteristics determine the semiconductor manufacturing system an extremely complex system. It is difficult to analyze and optimize semiconductor manufacturing process.

For this complex system, it is difficult to build a mathematical optimization model, even if the model is built, model solving is most likely a NP problem because of its complexity and nonlinearity (Lu & Yuan, 2007). Therefore, it is difficult to solve the semiconductor manufacturing optimization problem with the traditional analytical methods. Currently simulation is considered as one of the most effective quantitative methods to deal with the complex system, which can deal effectively with the stochastic and dynamics of the complex system (Jin, Wang, & Gao, 2008). With the development of distributed technology, more and more people research the distributed simulation technology. The distributed simulation technology provides a new perspective for solving such issues. Compared to the centralized simulation technology, the distributed simulation technology has the following advantages: effectively solving the complex problems, improving the solving efficiency of the problems by using the parallel computing, and being in line with the distribution and heterogeneity characteristics of the complex systems' subsystems.

The distributed simulation technology provides an effective means for the semiconductor manufacturing process analysis and optimization. For the semiconductor manufacturing process simulation, there is a need for establishing a simulation platform to identify and solve problems in the semiconductor manufacturing. In

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terms of architecture design, High Level Architecture (HLA) is widely adopted in the distributed interactive simulation to build the simulation applications, which can solve the problems about the reusability of the different simulation application models and the interoperability among the simulation federations. HLA is a milestone in the distributed simulation, which has solved the problems about data collection, analysis and simulation management in the advanced distributed simulation (Breckenridge, 2003). HLA provides the basic time management services for the distributed simulation, and RTI coordinates the time synchronization among federates. In terms of development technology, the multi-agent technology (Wong, 2006; Lo'pez-Ortega, 2009) is widely adopted in building simulation applications, in order to solve the intelligence, initiative and interactivity of federates. In the field of distributed computing, agent is considered as a computing entity which has a definite purpose and can run in the distributed environment independently and persistently, and it generally has the following main characteristics: autonomy, reaction, interaction and initiative (Chen & Tu, 2009; Fazel Zarandi & Ahmadpour, 2009). A multi-agent system consists of a number of agents that work together to find answers to problems that are beyond the individual capabilities or knowledge of each entity. These agents interact with one another, typically by exchanging messages through the computer network infrastructure. Cooperation and coordination between agents is the most important feature of multi-agent systems (Peng, 1998). The agent-based distributed simulation platform can be very good in simulating the intelligence, initiative of simulation members and realizing the distributed computing. At the same time, it can also solve the problems about the coordination and control among simulation members. As one of the mainstream tools for developing multi-agent systems, JADE has a lot of advantages. It can provide the graphical user interface for the remote agents and agent container management, help developers to develop multi-agent systems with its own debugging tools, has the good agent mobile performance, complies with FIPA standards, provides the FIPA interaction protocol library and supports the application-oriented ontology and expression language (Bellifemine, Caire, & Dominic, 2007). JADE is one of the best modern agent environments. JADE is open-source, FIPA compliant and runs on a variety of operating systems, which best supports the multi-agent system development (Meng, 2007). Therefore, the distributed simulation platform in this paper is developed based on JADE.

The purpose of this paper is to develop the distributed simulation platform which can simulate the semiconductor manufacturing process. Therefore, a multi-agent-based distributed simulation platform framework for semiconductor manufacturing is proposed, which can support the distributed simulation effectively, and a multi-agents collaborative control model is presented. A time synchronization model for distributed simulation is designed and steps of time synchronization are given. An interaction model and message formats are presented. Finally, we show the platform development and the evaluation of the platform with a case study.

The rest of this paper is organized as follows: Section 2 describes the multi-agent-based distributed simulation platform architecture. Section 3 describes the time synchronization model. Section 4 outlines the interaction model and message formats. Section 5 describes the platform development. Section 6 presents the platform evaluation. Section 7 is conclusions.

2. Multi-agent-based distributed simulation platform architecture for semiconductor manufacturing

2.1. The proposed platform framework

The multi-agent-based distributed simulation platform framework consists of three layers like network communication layer, JADE middleware layer and simulation application multi-agent layer, shown in Fig. 1.

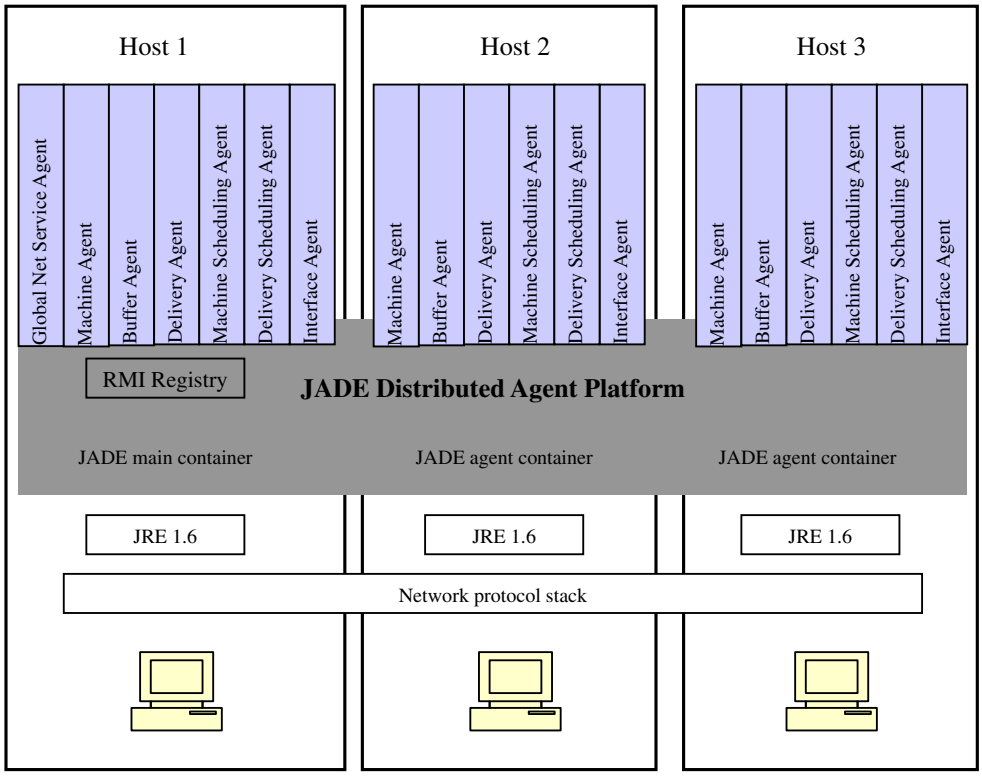

Fig. 1. The proposed platform framework.