The Application of Intelligent Agent Technology to Simulation

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Abstract We have been successfully applying Intelligent Agent Technology to several realworld simulation problems such as semiconductor manufacturing process, train operation, and electric motor assembly line.

Agent Technology is a methodology to realize an autonomous decentralized system with cooperative interactions between agents that model each element of the system. An Intelligent Agent has problem solving and learning skills, as well as the knowledge for that purpose. Agent is characterized as to have Autonomy, Sociality, Reactivity and Proactiveness.

In the development of a software system using Agent Technology, each element of the system is described in an independent and modular program code. This method makes addition, change and deletion of an element much easier than the case of conventional programming. In the realworld system, each element works mostly in an independent and parallel manner yet with interactions with each other, and matches well with the concept of agent.

We have chosen a platform called the PIM, Parallel Inference Machine, that describes and executes multiple agents in the independent and parallel manner. It makes the simulation application software development for a realworld system much more straightforward than conventional computing platforms.

This paper describes the agent technology, its application to realworld simulation and the platform "PIM." It describes in some detail actual simulator application examples: semiconductor process system management, train operation management, and electric motor assembly line change.

1. INTRODUCTION

Simulation models the real world. Simulations are used to verify hypotheses before committing to actual deployment. They allow the technologist to ascertain crucial aspects of a system in the computer world. All models and simulations are, by definition, imperfect. The precision and complexity of simulations are tightly coupled. The precision of modeling varies according to the purpose of simulation. The modeling precision may be increased, i.e., made to more closely resemble the real world, but doing so results in increased complexity and increased response time.

This paper describes the application of agent technology to modeling. Application examples are discussed. The advantages of the PIM (Parallel Inference Machine) in real time complex situations are detailed.

2. INTELLIGENT AGENT TECHNOLOGY

2.1. The Intelligent Agent Technology Approach

2.1.1. Overview

Agent Technology is a new approach in software development. It is a methodology to model each system component as an intelligent agent (hereafter agent) to solve simple problems, and realize the objectives of a whole system through such interactions between individual agents.

The characteristics of agent are as follows:

(1) Autonomy: capable of making judgments and solving problems utilizing knowledge and information.

(2) Sociality: solves problems cooperating and

coordinating with multiple agents.

(3) Reactivity: recognizes the environment and responds properly to it.

(4) Proactiveness: plays a proactive role in processes and work necessary to achieve goals.

The agent is conceptually defined to recognize the environment through sensors, decide internally the responsive actions, and act on the environment through effectors. See Figure 1.

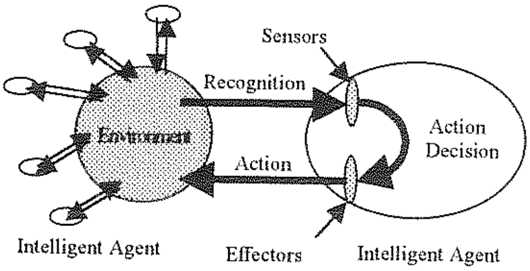


Figure 1 Conceptual Diagram of Intelligent Agent

2.1.2. Software Considerations

Software development based on agent technology divides a problem into parts to solve problems. Each agent is independent. This software building process is different than the conventional one. In normal software design (top down), modules are piled up on each other as building blocks. Any change or addition to a program module affects other modules which are based on that particular modified module. This is one of the causes of the year 2000 problem.

With agent technology, each function is made as an independent program (Figure 2). Any change or addition affects only the agent to be modified. Partial changes are non-destructive.

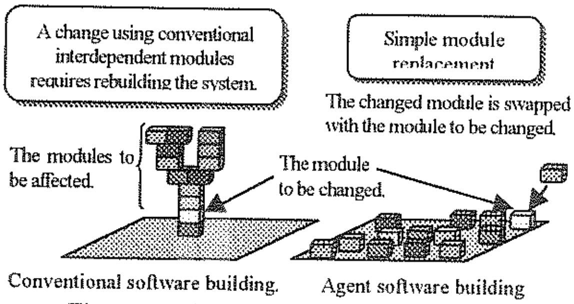


Figure 2 Software building difference

2.2 Platform for Simulation Development

A platform to execute parallel agents is needed. We adopted the following platform for simulation development.

2.2.1. Parallel Fixed Scan Processing Computer: PIM

The PIM is, as shown in Figure 3, a parallel fixed scan processing computer capable of executing in parallel thousands of individual program modules. It has a global memory accessible by all of the agents. Each program code or agent imports the necessary information from the global memory, makes judgments, and exports the results back to the global memory.

Since reading from and writing onto the common memories are synchronized, Data and program idiosyncrasies are minimized.

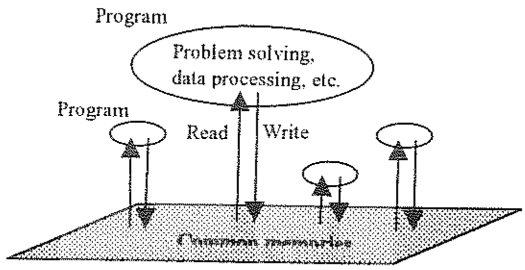


Figure 3 PIM Theory of Operation Diagram

2.2.2. Personal Computer

A personal computer connected to the PIM via TCP/IP is used to display PIM operations. The development environment runs on the same personal computer. Figure 4 shows a basic simulator system configuration.

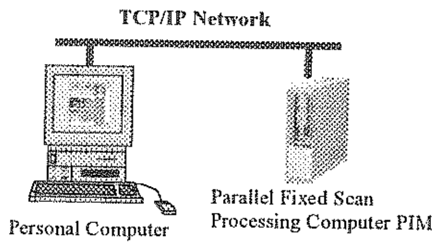


Figure 4 Simulator System Configuration

3. APPLICATION EXAMPLES

This chapter describes application examples.

3.1. Semiconductor Manufacturing Material Transfer System

3.1.1. Overview

Semiconductor manufacturing material transfer systems have the following issues.

(1) A semiconductor manufacturing process needs tens to hundreds of processes.

(2) Repetitive processes to pile up layers on the wafer makes the production planning difficult.

(3) It is difficult to identify bottlenecks in the production planning (scheduling).

(4) It is difficult to manage cascading effects caused by equipment failure.

Figure 5 shows a sample factory layout to simulate a preprocess of semiconductor manufacturing, consisting of five working bays A to E, 64 pieces of equipment 1 to 64, and transfer devices carrying wafers within and between the bays. We have built a simulator by modeling the equipment and devices in the factory and the evaluation functions for the factory productivity as agents.

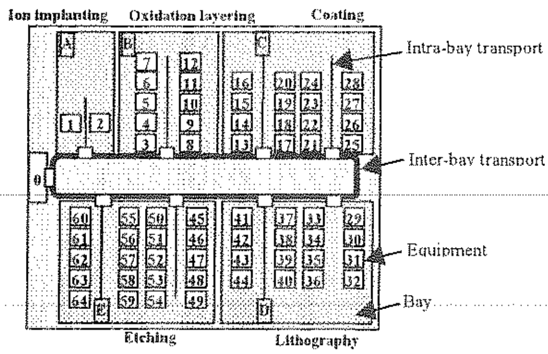


Figure 5 Semiconductor Manufacturing System factory layout

Figure 6 shows the wafer flow through the whole 33 wafer manufacturing processes. This simulator includes a scheduling function to have the wafers efficiently go through the processes as planned, and to route the wafers to the various devices for processing.

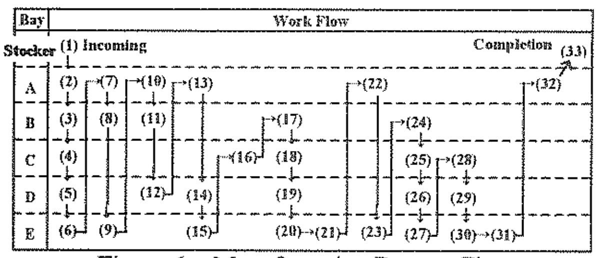


Figure 6 Manufacturing Process Flow (The whole 33 processes)

This simulator is expected to give the following effects:

(1) To identify the bottlenecks (points prone to lot jam) in the transfer system, and contribute to the efficiency increase of the transfer system.

(2) To verify the production plan (lot flow) before actual manufacturing and improve the precision of delivery control.

(3) To estimate precisely the performance of the planned transfer system before actual operation, examine the operation including the production plan, and improve the factory management.

3.1.2. Features

The use of conventional simulators is limited to examination. This simulator is first used to examine the optimum scheduling method for the wafer transfer system, and then can be used as the actual controller. Since there is no need to transport the control logic created in the simulator to another control computer, the programming and other errors in the porting process can be avoided.

This simulator is capable of:

(1) Modeling each pieces of equipment and device, the transfer system (conveyors), the scheduling function and the system evaluation function as agents.

(2) Realizing any equipment failure by simply stopping the equipment agent, the system behavior is as realistic as the actual system, and is a high precision simulation.

(3) Adding and replacing new equipment and device agents even in program execution.

(4) Creating the system evaluation agent without modifying the equipment, device and transfer system agents.

We have developed a scheduling product based on this simulator. The scheduler has reduced the production time by approximately 10% compared to the production by the conventional scheduling method at the sample factory described above. See Figure 7.

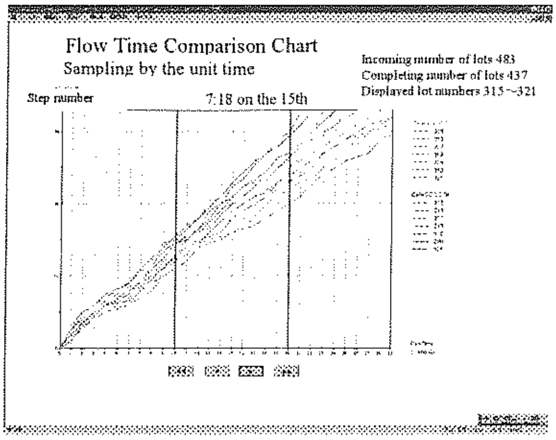


Figure 7 Flow Time Comparison Chart

3.2. Train Operation Control

3.2.1. Overview

With a train operation system, the following points must be considered:

(1) A train operation system consists of the part of upper level computers for track switch control and other management functions and the other part of field facilities such as track switches and signals.

(2) It is mandatory to perform a thorough test with as precise a simulator as the real system when a new system is installed or a new train operation control method is introduced.

(3) It is difficult to realize a real-time simulation because the actual operation includes as many as 130 trains running at a time and thousands of station facilities such as track switches and signals.

(4) It is difficult to model each function enough for developing as realistic a simulator as the actual facilities.

We have developed a simulator to realize a detailed train operation simulation at a train operation system including many trains running at a time. The field facilities of the train operation system are modeled in the simulator system on the PIM. They are the test and train schedule management, the operation facilities and the train run. The simulator system is connected to the upper level computer. See Figures 8 and 9.
Each train is modeled as an agent. Each train runs according to the schedules.

This simulator enables the following additional features:

(1) Training the train dispatchers on a simulator system that is capable of running the same number of trains according to the same schedule as the actual train operation system, without setting up a separate actual facilities for training.

(2) The simulation precision is proved to be enough to reproduce the train operation disruption by comparison with the actual disruption data. The simulator is applied to the verification of new control logic, train control scheme improvement and new train schedules. The time for application of a new logic to the actual operation can be reduced.

3.2.2. Features

It is difficult to realize a real-time simulator with any conventional computer and software development method. The combination of the agent technology and the parallel computer solves the usually intractable tradeoff between the precision and scale and the real-time and development cost of simulation. It realizes a high-fidelity real-time simulation of interactions between multiple parallel events.

This simulator has these features:

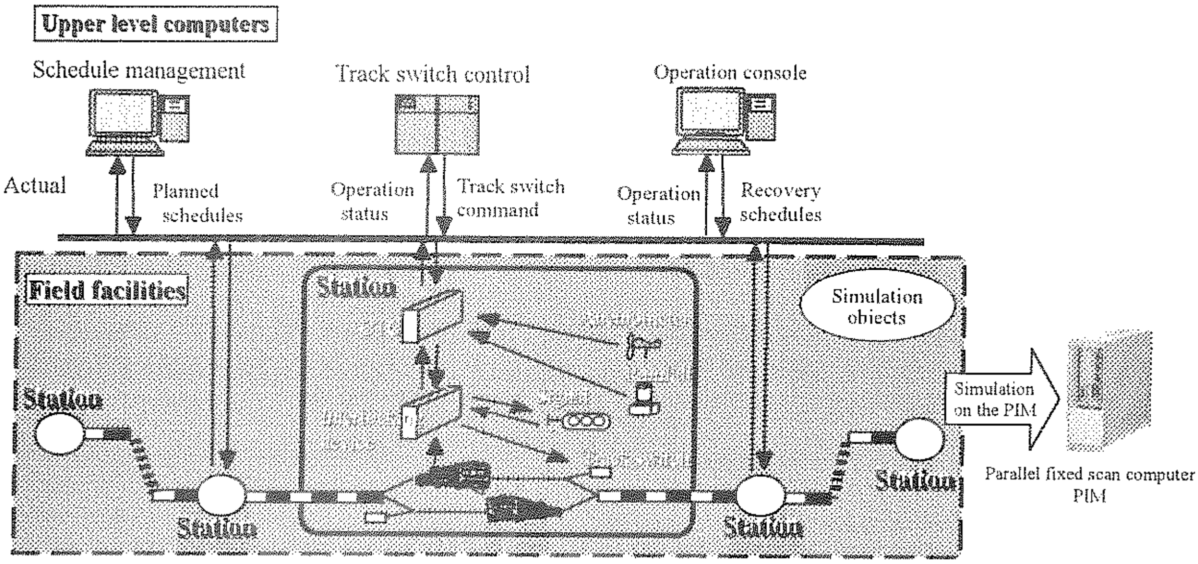
(1) Modeling the station facilities and trains as agents.

(2) Realistic simulation according to the train schedules taking the actual train run conditions into consideration.

(3) Easy creation or reproduction of an unusual situation caused by an operation facility failure or train failure.

(4) Realistic creation or reproduction of a train operation disruption by forcing a train agent to a fail.

(5) Real-time simulation of as many trains as are actually running.



CTC: Centralized train control system

Figure 8 Train Operation Control System Configuration

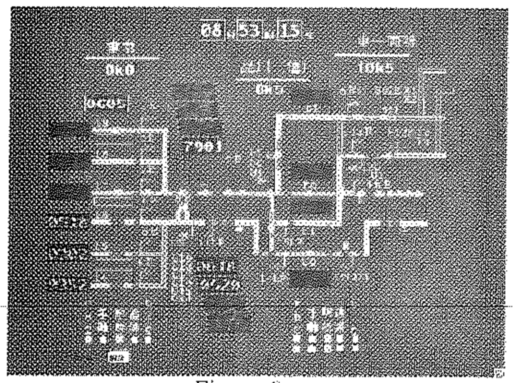


Figure 9

3.3. Production Line Simulator

3.3.1. Overview

Our electric motor production lines have the following issues:

(1) Verification of the number of buffers at each process before changing the motor assembly line layout.

(2) The assembly line consists of 13 processes.

(3) Each production lot needs a different combination of the processes.

(4) Estimation of the production line productivity of a new layout is necessary.

(5) Verification of the appropriateness of a production plan is necessary.

We have developed a simulator to estimate the number of buffers at each process and the productivity of a new layout before the electric motor assembly line layout is changed, solving the issues described above.

This simulator enables the following features:

(1) The estimation of the productivity of a new assembly line is reflected in the production plan and leads to an improvement of delivery control.

(2) The identification of the bottleneck before the production lots are actually run at a new line enables the adjustment of the number of buffers before starting the operation and contributes to the productivity improvement at the operation.

3.3.2. Features

The customization available with general purpose production line simulators is quite limited, making it difficult to build a realistic simulator. Using agent approaches and the PIM we have developed a production line simulator to realize the verification before operation, taking the detailed specifications needed for our electric motor assembly line into consideration.

This simulator is characterized as:

(1) Modeling the processes and the line performance evaluation as agents.

(2) The process agents and the line performance evaluation agent are independent from each other. The evaluation agent is able to do an objective evaluation of the line. The evaluation program codes need not be embedded in the process program codes as in a conventional software development.

(3) Productivity verification before operation of a production plan on the new production line.

Figure 10 shows one of the simulator screens.

This simulator is actually applied to obtain the optimum solutions for the items described above, and they have been applied to the new production layout.

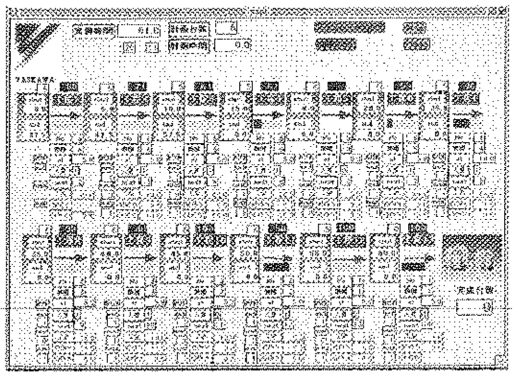


Figure 10 A Screen of Production Line Simulator

4. CONCLUSIONS

We have described the simulation application examples of intelligent agent technology on the platform of the PIM. The combination of the intelligent agent technology and the PIM enables modeling each system component as a simple agent, easily synthesizing a complex system combining the agents, and realizing a precise simulation. Since the simulators described here model the equipment and devices of the target system as agents, replacing the equipment and device agents with the communication agents for the actual equipment and devices enables the use of the simulator for monitoring and even a controlling the target system.

We will continue to apply the agent technology to various areas from simulation to control.

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