行政院國家科學委員會專題研究計畫　期中進度報告

總計劃(1/3)

計畫類別：整合型計畫
計畫編號：NSC92-2213-E-002-097-
執行期間：92年08月01日至93年07月31日
執行單位：國立臺灣大學工業工程學研究所

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報告類型：精簡報告

處理方式：本計畫可公開查詢

中　華　民　國 93年6月25日

12 吋晶圓製造服務佳化工具與標竿環境之研發(1/3)

Design and Development of Benchmark Environment and Optimization Tools for 300mm Foundry Manufacturing Service(1/3)

計 畫　編 號：NSC92－2213－E－002－097
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執行期限：92 年 8 月 1 日至 93 年 7 月 31 日
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一、中文摘要

這是為期三年的『12 吋晶圓製造服務佳化工具與標竿環境之研發』計劃的第一年。本計劃的主要目的是要建立一個可以整合不同佳化工具和相關資料數據的標竿環境。佳化工具由四個子計劃個別設計研發。我們利用物件導向的分析方法和軟體整合來設計並架構此標竿環境。標竿環境的架構包括一座網路伺服器，一座資料庫伺服器與一個佳化工具伺服器。在資料庫伺服器中，我們應用 PostgreSQL 來當作我們的資料庫管理系統軟體。在網路伺服器中，我們採用 Appache 作為內部的伺服器而採用 PHP 作為連結網路伺服器和資料庫間的中介層，同時 PHP 的使用也會使網站上的動態服務更加靈活運用。我們利用 HTML 語法以及 PHP 內嵌程式來建立標竿環境網站；未來將運用 Java Script, CSS 等網頁撰寫技術來製作標竿環境網頁。

關鍵詞：標竿環境、十二吋晶圓製造、佳化工具、資料庫、網路伺服器、物件導向分析

Abstract

It’s the first year of 3-year project—“Design and Development of Benchmark Environment and Optimization Tools for 300mm Foundry Manufacturing Service”. The objective of this project is to establish a benchmark environment and to integrate data sets and individual optimization tools into it. Individual optimization tools will be designed and developed by five subproject hosts. The method to construct a benchmark system includes adopting object-oriented technology for system analysis, design and software implementation. The configuration of this benchmark environment will include one web server, one database server, and one optimization tool server. Within the database server, PostgreSQL is adopted as the database manipulation software. Our web server adopts Apache as the web server and will use PHP as the scripting language to connect the web page stored in the web server to the database server. PHP will also add interaction functionality to our web page to users from outside. The web site will be built with HTML language with PHP embedded to enhance its functionality. Other web page technique, such as java script, CSS, may also be added in the process of website building.

Keywords: benchmark environment, 300mm foundry manufacturing, optimization tools, database, web server, object-oriented analysis

二、研究動機與目的

Continuous optimization of the factory as requirement change is one of the six difficult challenges for factory integration identified by the International Roadmap for Semiconductors, 2001 Edition. Motivated by the needs for advanced optimization methods and the uniqueness and strength of Taiwan’s foundry manufacturing, we propose a three-year research to design and develop not only a set of optimization tools but also a benchmark environment for 300mm foundry manufacturing service provisioning. Our objective aims at conducting a world leading research and it has three folds:

1. design and develop of **advanced optimization tools** to facilitate an efficient, quality and reliable service,
2. establishment of **model and data bases for optimization**, which expose industrial people to the underlying fab characteristics and provide the academia with realistic data for research, and
3. construction of **an easily accessible benchmark environment** for manufacturing service optimization.

To achieve the objective, we planned one main project and five subprojects on optimization of foundry services:

Subproject 1: Research on Enabling Technologies for Collaborative Planning and Scheduling in Semiconductor Manufacturing;

Subproject 2: Research on Simulation-based Ordinal

Optimization Methods with Applications to Production Scheduling of 300mm Foundry Fabs;

Subproject 3: Shop Floor Control of Hot Lots in 300mm Wafer Manufacturing;

Subproject 4: Evolutionary Process Optimization Methods for Multi-stage Manufacturing Systems with Applications to Semiconductor Yield Rump-up.

The main project aims at establishing a benchmark environment and integrating the data sets, models and optimization tools of individual subprojects into it.

三、研究進度與成果

Figure 1 illustrates the 1st year progress of our main project. The progress and achievement are discussed in the following two aspects:

Ｉ. Benchmark Configuration

In the first year of 3-year project—"Design and Development of Benchmark Environment and Optimization Tools for 300mm Foundry Manufacturing Service," our objective this year is to establish a benchmark environment and to integrate data sets and individual optimization tools into it. The configuration includes **one web server**, **one database server**, and **one optimization tool server**. As illustrated in Figure 2, the web server will be installed into one machine and the database server and optimization tool server will be installed into the other. Within the database server, **PostgreSQL** is as the database manipulation software, providing SQL database operation functionality such as query and table joint. The manipulation interface is illustrated in Figures 3 and 4. Figure 3 is the traditional interface which could work under ordinary OS. Figure 4 is a GUI through software **phpPgAdmin** which will work together with PHP and its own software.

Our web server adopts **APACHE** as the web server and will use **PHP** ase the scripting language to connect the web page stored in the web server to the database server. PHP will also add interaction functionality to our web page to users from outside. The configuration of our web site is listed in the Table 3. The web site will be built in HTML language with PHP embedded to enhance its functionality. Other web page technique, such as java script, CSS, may also be added in the process of website building.

The users who will access to the web site will be classified into different groups: *project hosts, registers, and non-registers,* authority to the website will also be classified according to the three groups. In the first-draft configuration the website will include the following four functionality:

1. access to **advanced optimization tools** designed and developed by each sub-projector
2. access to **models and database servers**
3. **technical document** provided
4. a friendly accessible GUI

We have installed these two servers have been in Room 106, GIIE, National Taiwan University. We also installed LINUX, PHP, and APACHE in our servers. Right now, the simulation platform is set within the database server equipment; that is, web server and database server are operated within one machine in this stage, in the future, the two servers will be separated into two different machines to be operated.

II. Hardware Requirement & Specification

Database Server & Optimization Tools Server

The hardware specifications for the database server includes stability and extensibility described as below:

Stability

To handle the amount of data accessing by external users around the world the database server should be stable enough to decrease the possibility of unexpected incidents like crash and breakdown. Meanwhile, database backup system also will be a very important issue in case of the inevitable accidents.

Extensibility

To cope with the budget limit of Year 1 by this plan and make the best use of the money in the foresight of future, one solution is purchasing an easily extensible system. Our system could be upgraded in the future when components like Hard Disk, RAM, second-CPU are configured into the existing instrument.

Web Server

The need for a stable system to handle the flow of Internet information is the main concern when we choose the hardware for the web server. In the web server, its role is an entrance to our environment. A superior PC-level computer could follow the task because the focus of our system will lay on the database server, which may control the most part of our environment system and decide the stability.

III. Summary of Subproject 1

Collaborative planning has been shown to be very effective in improving the quality and speed of decisions in supply chain management. This project proposes to develop enabling technologies for collaborative planning in semiconductor manufacturing. Because the participants of collaboration are influenced by their own interests and corporate objectives, economic analysis and risk analysis are essential elements of planning. Therefore, this project proposes to address two enabling technologies of planning: 1) marginal value models for capacity, output schedule, and inventory information and 2) collaborative scheduling methodologies. Figures 4 and 5 depict two of the 1st year results: collaborative machine assignment and scheduling design pattern and a design of system architecture of constraint satisfaction engine.

IV. Summary of Subproject 2

In the past 10 month of research, subproject two has been focused on the design of *ordinal optimization-Based Dynamic Programming (OODP)* methods to handle the combinatorial complexity of scheduling policies over the time axis. Progresses have been made in the design of a simulation-based ordinal policy iteration algorithm and the design of contract algorithm for dynamic allocation of computation budget.

IV.1 Design of Simulation-Based Ordinal Policy Iteration Algorithm (SBOPIA)

This algorithm (Figure 7) is designed for dynamic optimization problems where the stage-wise cost function is so complicated that it can only be evaluated by simulation. Given estimated optimal cost-to-go and the corresponding decision policy, SBOPIA applies simulation to evaluate stage-wise costs and ordinal optimization to find the good enough decision for each state. This procedure iterates until convergence to a fixed decision policy. Preliminary numerical study demonstrates the feasibility and potential of the algorithm. Simulation experiment, convergence proof, computation efficiency analysis and have been under way.

IV.2. Design of Contract Algorithm-based Computation Budget Allocation (CABCBA)

To efficiently search over the large state space under processor capacity and run time limits, there needs a method to properly allocate computing budget. We have been investigating the notion of *contract* algorithms (Zilberstein, Charpillet, and Chassaing, 2003), where the solution quality of an algorithm improves as the allocated amount of computation time increases. Exploiting the design of SBOPIA, we are establishing a stochastic performance profile $P_A(q|t)$ denoting the probability of getting an optimal-cost-to-go estimate of quality q with budget time t by the SBOPIA algorithm. Dynamic computing budget allocation will then be designed based on such profile.

V. Summary of Subproject 3

This first year research of efforts supported by this subproject has three parts. In the first part we deal with the problem of providing differentiated material handling services in a highly automated environment of 300mm semiconductor manufacturing. We propose a preemptive dispatching policy to expedite the movement of high priority products while keeping the incurred delays on regular ones being acceptable. Simulation experiments based on realistic data from a local 300mm foundry fab are conducted. Numerical results demonstrate that the proposed policy is sound in reducing the transport delay of high priority products to the extreme. Some features of the policy are also explored.

The second part is motivated by an interesting phenomenon from the dynamics of automated vehicles in 300mm semiconductor manufacturing: After evolving with time, all the vehicles around a unidirectional circular loop become a long train of vehicles, whatever the initial distances between any two adjacent vehicles are. We call it "Vehicle Chaining Phenomenon" or *VCP* as shown in Figure 8. We explore the causes of this phenomenon and clarify its impacts on job waiting time. An optimal vehicle control policy is then developed to avoid the performance deterioration due to this phenomenon. Computer simulations are conducted to demonstrate the effectiveness of our estimates to the average job waiting times.

In the third part, we adopt Petri nets to model the coupling dynamics among transport jobs and OHT vehicles in an intrabay loop. The congestion phenomenon among OHT vehicles is captured. The OHT scheduling problem is then formulated into an integer programming problem whose goal is to efficiently allocate OHT vehicles to jobs such that average job delivery time is minimized. A solution methodology that combines Lagrangian relaxation and the surrogate subgradient methods is developed. Numerical results demonstrate that our solution methodology can generate good schedules within a reasonable amount of computation time for realistic problems.

VI. Summary of Subproject 4

Models of manufacturing systems have evolved over the years from divided functions within a company to integrating a company's efforts and resources and now to a new business model with companies focusing on different aspects of a product. The birth of this new business model is due largely to the very different characteristics of modern hi-tech products. Unlike conventional commodities, hi-tech products usually have a very short life cycle. To speed up the time-to-market process, companies responsible for the product's original design, usually also being the product owners, have turned their back on manufacturing issues. To shorten the time to market, they seek reliable manufacturing companies as their business partners to take care the manufacturing aspects of the product. Very often, these companies release product designs that are immature and untested and rely on their partners to refine the design during the manufacturing stage. Therefore, manufacturing companies nowadays have to provide a wide spectrum of services that include proprietary IP's for product designs and manufacturing process development. TSMC, Taiwan Semiconductor Manufacturing Company, has championed such a foundry service model and enjoyed a great success in the semiconductor sector. Many companies of various sectors in Taiwan are following such a model and intend to evolve from low-value-adding manufacturers to high-value-adding manufacturing services providers.

To become a successful manufacturing services provider, a speedy yield ramp-up during the early stage of product/process development is critical. Because of the increasing complexity of modern manufacturing processes, to ramp up production yield is no easy problem. A typical semiconductor fabrication process consists of more than 300 steps. Too many possible factors during the process could contribute to the low yield. Nevertheless, no systematic solutions exist as far to this problem. Even for a successful company like TSMC, the yield ramp-up process remains to be a tedious, time-consuming task of swarming process integration engineers. Even though many techniques have been developed over the years aiming to continuously improve yield or product quality during the manufacturing stage, the practitioners have mostly overlooked these techniques. It is this project's mission to take up again these techniques and to develop an effective, systematic yield-ramp-up solution. These techniques are developed by different research communities but have a common goal: *to on-line continuously optimize the process performance*. They include: evolutionary operations (EVOP), an on-line design of experiment (DOE), technique first developed by Box, an applied statistician, in 60's; Optimum Experimental Design (OED) and Ridge Analysis (RA); perturbation-based real-time optimization (PRTO) techniques by Chemical process control researchers and Mathematicians; and Ordinal Optimization methods by discrete-event control researchers. We summarize the comparison of above methodologies in the following table:

Table 1 Comparison of on-line optimization methods

	Physical Model	Empirical Model	Sequential Experiments	Process Perturbation	Steady State Model	Dynamic Model
EVOP		♦	♦		♦	
RTO	♦	♦		♦		♦
OO	♦		♦			♦
OED/RA		♦	♦		♦	

Based on the comparison, we develop a methodology combining concepts of OED/RA and OO. We propose a novel measure $|\Lambda^{-1}|$ that evaluates how reliable the estimated improvement path is (confidence region of an estimated ridge path). We call this measure an "R-criterion" and use this criterion to sequentially design on-line experiments. Figure 9 shows how an original designis sequentially augmented by adding new design points. Grey dots represent original experimental design and its improvement path is represented by the grey-star curve. The green point in Figure 1 is the first design point added and the green doted curve is the correspongding improvement path found. The reliability of the improvement path is then continuously improved through new design points in red, blue and purple. As can be seen, the improvement path converges as more design points are added.

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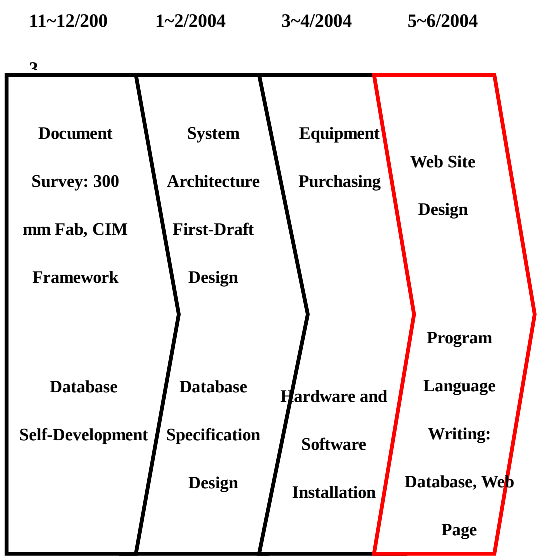

Figure 1.　Year 1 Progress Chart

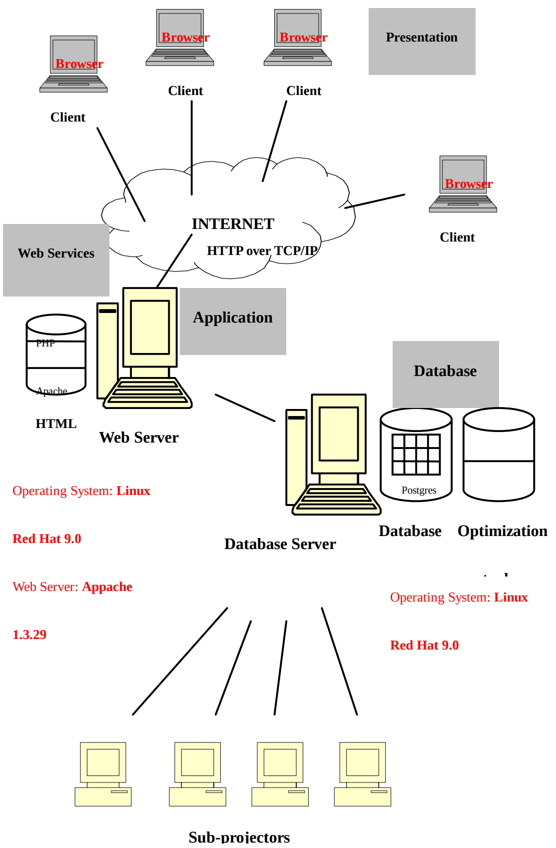

Figure 2. System Configuration of the Benchmark Environment

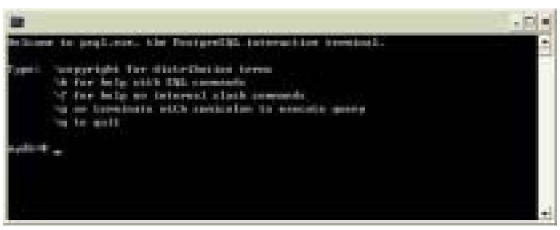

Figure 3. Interface in PostgreSQL

Figure 4. GUI of PostgreSQL

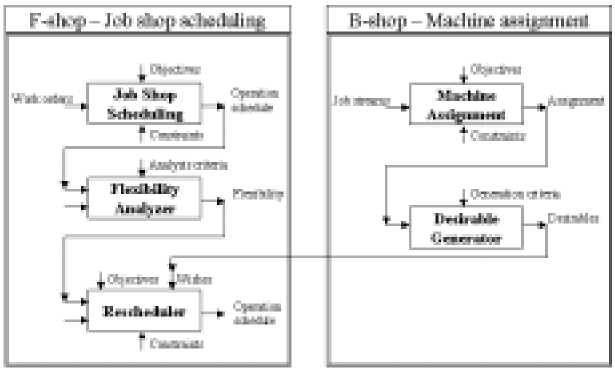

Figure 5. Collaborative Machine Assignment and Scheduling Design Pattern

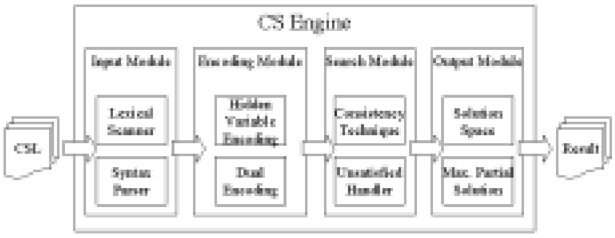

Figure 6. System Architecture of Constraint Satisfaction Engine

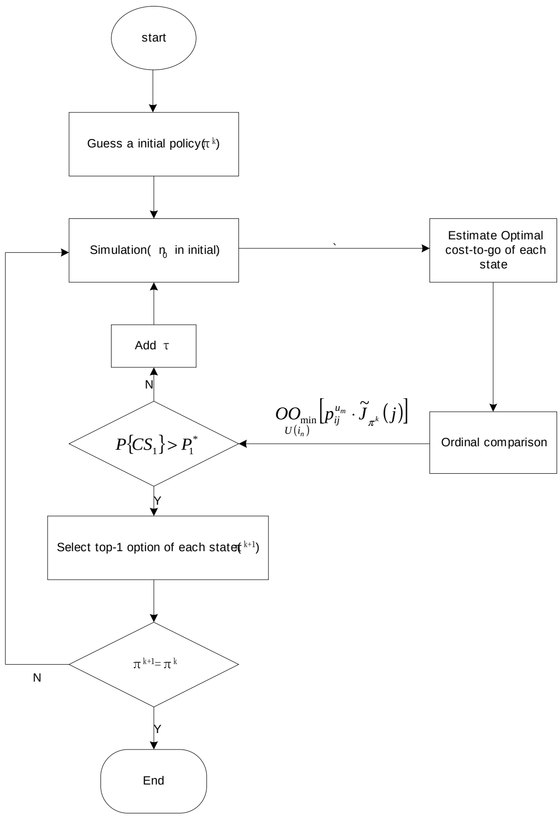

Figure 7. Flow Chart of Ordinal Optimization-based Policy Iteration Algorithm

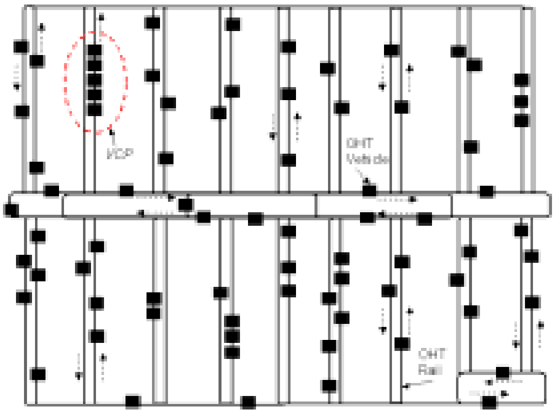

Figure 8. VCP in Tandem OHT Layout

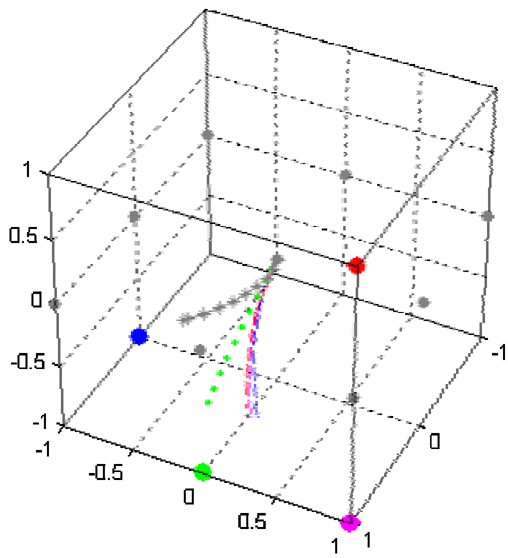

Figure 9. Evolutionary Improvement Paths by R-optimum Experimental Design