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OPTIMIZATION AND ANALYSIS OF PERFORMANCE IN SIMULATION

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ABSTRACT

Simulation in manufacturing has traditionally been used for high level capacity planning. Simulation use is rapidly growing in other fields such as scheduling, detailed equipment models, and application specific models for use in emulation, engineering,sales and marketing. This growth can be attributed to the ability of simulation software tools to more accurately model manufacturing and material handling operations than with traditional simulation tools. It is not unheard of today to havethe ability to create a model of an automated system with near 98 percent accurate representation. Much of the recent focus from software vendors has been to increase the ability to accurately depict manufacturing operations. Until very recently, the simulation industry suffered greatly with its inability to analyze complex manufacturing systems in enough detail to provide optimum or near-optimum solutions to the problems being addressed.

1 INTRODUCTION

The manufacturing industry believes in general that simulation and optimization are not synonymous. Simulation is felt to provide one result for an experiment. The single case result may or may not be the optimal solution, as the single case provides just one result based on the settings used for that experiment. This paper briefly describes how Applied Materials has developed an application-specific model for analysis and experimentation of tool performance. Applied Materials has integrated their simulation with analytical tools to seek optimal or near-optimal solutions to problems presented. One focus of Applied Materials' studies is on system optimization.

2 USE OF SIMULATION

Applied Materials has used simulation for more than six years to predict equipment performance and capacity planning for cluster tools. The use of simulation has grown from back of the envelope calculations, to static models, to capacity analysis mode,to using simulation as a test bed for optimization. Simulation has been used to help understand many performance issuesand to provide a mechanism of testing new and improved procedures. Recently, Applied Materials has started using optimization for analysis of their equipment. Historically, this type of analysis has been a difficult and time-consuming task for users. Automating optimization provides better results and requires less effort from the user.

3 APPLICATION-SPECIFIC MODELS

The simulation industry is seeing a trend toward development and use of more application-specific models. These run-time models or templates are constructed from general-purpose simulation languages and are geared toward specific applications. Applied Materials and AutoSimulations have developed an application-specific modeling tool for simulation of Applied Materials' cluster tools. There are several advantages in building application specific simulation tools:

1. Application interface for input and output can be constructed in the terminology familiar to the end user.

2. Existing systems can be modeled with a high degree of accuracy.

3. The application can be used by engineers, not just simulation experts. (The template or application model is developed by an experienced simulation practitioner, not the engineer.)

4. Models can be built to investigate optimal or near-optimal solutions to a set of specific problems

5. Future system requirements can be tested with existing templates.

4 CLUSTER TOOLS

The cluster tool, one of the primary tools in semiconductor manufacturing operations, consists of robotics, process chambers and an enclosed vacuum work space. All components are kept as a contamination free manufacturing environment. These tools perform specific manufacturing operations on semiconductor wafers. The wafers, after being diced into individual parts (chips) eventually become the Integrated Circuits parts which are embedded in personal computers, games, and other electronic products.

A cluster tool is basically a small factory. It has all the components of a factory such as: products, product routings, resources, and product demand. Figure 1 provides an example of a vacuum cluster tool. In this schematic, cassettes of 25 wafers are placed in the load locks which are used to stage and store wafers between the atmospheric conditions and the vacuum environment transfer spaces. Once in the vacuumspace, the parts are transported by a robot to process chambers, in this case individual wafers are processed first at Etch then at Strip then back to the load lock. The product then leaves the clean environment through the load locks.

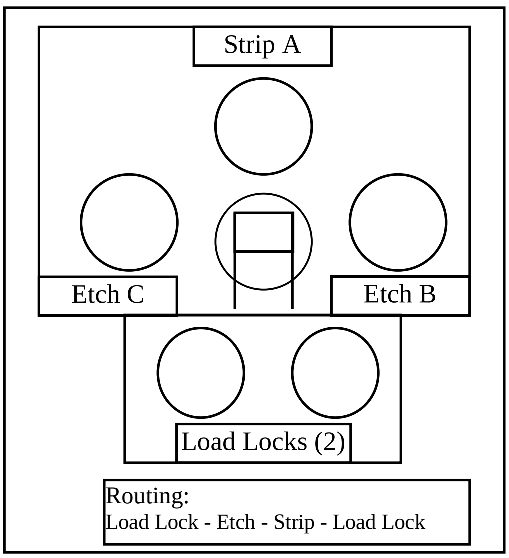

Figure 1: Schematic of a Cluster Tool

5 APPLICATION INTERFACE

The application itself is layered on top of an object oriented simulation package known as AutoSched AP. The application interface is an MFC based tool that utilizes Excel to provide data and factor input into the model, as well as to present results of simulation runs and analysis. The data input and output terminology are common in equipment tool manufacturing, thereby minimizing the simulation experience required of the user. The application development and product maintenance is performed by an experienced simulation developer and programmer. The application is for internal use by Applied Materials' engineers. One application is for capacity analysis; evaluation of equipment performance for specific cluster tool configurations (robot + process chambers + process routing). Another use is for researchers and scientist at Applied Materials to evaluate performance optimization.

Figure 2 depicts the cluster tool modeling environment and tool architecture. The user has a model controller for selecting an existing model, creating new models, and for deleting existing models. The controller application also has security restrictions for different user levels. Once a model is selected, that specific model is presented to the user. Excel is used for inputting data, setting up experiments, and reviewing simulation results. The model tool can be configured to simulate one run for a specific tool configuration. Experiments can also be madeon specific factors. Single factor or multiple factor experiments can be made to provide data for sensitivity test. Certain experiments have embedded optimization to determine what the optimal settings are for factored input.

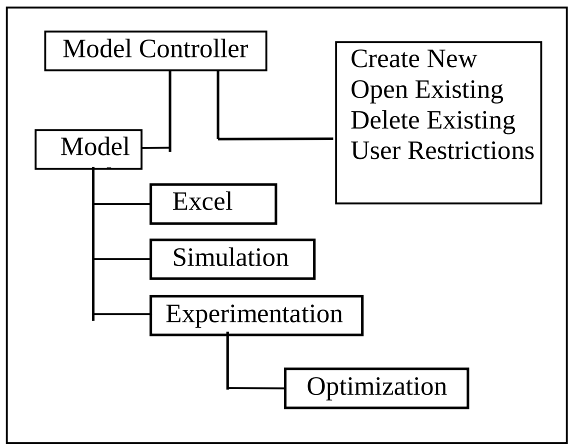

Figure 2: Application Architecture

6 MODEL ANALYSIS

There are several methods for analyzing a simulation model. To determine the best analysis method requires both the domain experience of the system being simulated as well as an understanding of the simulation tool and its capabilities. Very few software packages today offer optimization as a standard feature for model analysis. Most however, do provide a set of statistical analysis tools: such as design-of-experiments, confidence intervals, warm-up determination, and simple goal seeking. A primary reason for the exclusion of optimization tools is that general-purpose simulation products are used to address such a wide spectrum of applications that understanding how optimization fits has been difficult. More specific model have several advantages to optimization solutions.

As models become more application-specific, the model objectives and problem domain also become more specific and bound, allowing for opportunities to utilize more advanced analysis techniques. With Applied Materials' model, the problem domain is both reduced in size as well as focus. In the case of Applied Materials' model, depending on the model configuration, run times are approximately 2 to 5 seconds (PC dependence) for one execution of a model experiment. Because of the system size, constraint focus, and modeling runtime performance, this application can take advantage of many types optimization solutions.

7 OPTIMIZATION

One of Applied Materials' optimization objectives is to maximize system throughput. This requires investigating all the sensitivity to all the variables in the model. In addition to other variables Applied Materials' has a finite number of rules to investigate for their robots, such as FIFO, least travel distance, or highest processing time. By experimenting through this finite set of scheduling or dispatching engines, Applied Materials could seek the overall best wafer movement schedule to use for a specific tool configuration. But this might not provide the optimal wafer throughput for the tool.

8 CONCLUSIONS

Applied Materials' use of engineering and application interface is unique and is not often found in manufacturing or simulation industry. The problem domain is bounded such that a full search of possible results can be tested. For larger scale systems, a more elegant or elaborate optimization would have to be employed.

Applied Materials has considered implementing additional constraints. This will significantly increase the number of possible solutions that need to be tested. The options for Applied Materials are to still attempt to test every possible case or possibly investigate the use of some other optimization method. Other generic methods that would fit this architecture include genetic algorithms, simulated-annealing, and Hooke-Jeeves pattern search.

Historically the use of optimization in simulation has been limited. The potential gain and scale of effort with which it could be implemented, as in Applied Materials' case, suggest that the use of optimization has much potential in manufacturing and simulation industry. It would help both industries enormously if the software vendors would provide the core functionality for optimization in the base software packages. The user would have to only provide the optimization objective function, the variable and variable settings that can be modified, the constraints which have to insured, and the termination function. Generally the termination function can be defined by time or by someother gradient equation.

The software should then have a selection of potential variables that can be used to search for an optimal solution. This has been done successfully in the past, but it usually requires the user to develop an application which uses some optimization method, and which embeds the simulation tool. This capability exists, but it limits its use significantly in industry due to the domain knowledge required by the user.

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BIOGRAPHIES

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