Proceedings of the 1998 Winter Simulation Conference
D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds.

SIMULATION-BASED PRODUCTION CONTROL IN THE SEMICONDUCTOR INDUSTRY

Matthias Thiel
Roland Schulz
Peter Gmilkowsky

Technical University of Ilmenau
Faculty of Business Administration
Department of Business Related Computer Science I
PF 10 05 65, Helmholzplatz 3
98684 Ilmenau, GERMANY

ABSTRACT

The article deals with the development of simulation models for the semiconductor industry at the Technical University of Ilmenau. Hereby, the main focus is set on the development of methods and proceedings for the solution of the order sequencing problem. For this purpose the specific production conditions in a semiconductor factory have been analyzed. It was necessary to deduct various methods to represent all of these specific production conditions in one simulation model. Additionally to local methods the suggested solution integrates interaction and coordination methods as global oriented mechanisms into the problem solving concept.

As a result there is a simulation model available now. This simulation model supports the order sequencing on a coarse and fine level. Within the scope of the coarse sequencing, a forecast of the due dates of production orders is supported. By way of contrast, the fine sequencing has to determine an efficient order sequencing in relation to the actual production situation and the given objectives.

1 INTRODUCTION

One of the essential problems in controlling flexible manufacturing systems is to establish the order scheduling. Today this operative task must be executed while considering a flexible reaction for consumer demands, the economical aspects of a growing and fluctuating production program. Furthermore, the order sequencing must consider specific production conditions (see section 2).

Up to now there is no model for a control instrument that integrates the problems mentioned above. Present solutions offer a regulation instrument including dispatch rules and additional load and setup rules, but these regulation instruments neither regard the coherence of the individual rules nor do they represent the complete production control problem.

No possibility has been found yet to analyze the operative behavior of a semiconductor production in consequence of the high controlling-complexity. Simulation is the only way to predict the dynamic behavior of cycle times, throughput and capacity utilization adequately. So manufactures will gain an advantage, being able to integrate the full controlling-complexity in one simulation model.

The dispatcher should possess an instrument that allows him to simulate different strategies to examine different objectives. This would allow him to choose an order sequence while paying attention to the highly complex production conditions.

2 ANALYSIS OF THE SPECIFIC PRODUCTION CONDITIONS IN THE SEMICONDUCTOR INDUSTRY

The production control of the semiconductor industry is characterized through a multitude of specific production conditions and so it is a complex and difficult job.

These specific production conditions are (Fowler 92, Gurnani 92, Thiel 96):

- Technological conditions:
    - groups of the same type of equipment
    - charges (A charge is a temporary combination of several orders to a common work. The number of orders that can be processed in parallel on a facility is limited.)
    - sequence dependent setup times
    - conditional times (A conditional time specifies the maximum time an order can wait in the queue of a production segment. If the waiting time exceeds the conditional time,

the order is irreparably damaged or a repair is necessary.)
- Other conditions:
    - make-to-order production with fluctuating order size and order profile
    - urgency of the due date

A solution has to propose methods for representation of these production conditions in a simulation model. Indeed, all the production conditions do not necessarily occur at a workstation simultaneously. The solution has to consider this fact to be more flexible.

3 PROPOSITION OF A SOLUTION FOR THE PRODUCTION REGULATION PROBLEM

3.1 Survey to the Principles of the Solution

Concerning the high complexity and dynamics of production control, the feedback control circuit was selected as a general conception (Kahlert 93). Figure 1 represents the structure of the feedback control circuit. The base of this method is the conception of the production control as a regulator, which gives the strategies for controlling the production system as a regulation variable to the regulation system.

Production systems can be subdivided into different segments which allow to fulfill certain production tasks. Therefore a production segment can be seen as an agent. The agent uses various algorithms to solve the sequencing problem.

At the beginning of a simulation experiment, the current state of all production segments is taken over in the simulation model. Algorithms are started within the simulation model through different events (e.g. an order reaches a facility / a facility selects orders for the next processing). These algorithms are used on one hand to prepare a decision and on the other hand to decide themselves. In general, decisions have to be situation-related. The state of the production segment is evaluated and after that, the algorithm schedules the orders on the base of rule systems (see section 4.1). The different weighing of the rules allows the dispatcher to try different control strategies for a production segment. Through the simulation different control strategies were tested and rated by means of the objective system of the production system. At the end the best control strategy is submitted to the regulator.The simulation component is used at the global level of the production control. The necessity of a coordination between the different production segments is caused through the high interdependence, which results from the specific production conditions. To coordinate between the production segments interaction and coordination procedures are used.

3.2 Survey to the Structure of the Agent

As mentioned in the previous section, a production system can be subdivided into different segments. Every production segment has to fulfill different tasks.

Both production tasks and the equipment needed to accomplish the production tasks determine the production specifics and the required rule base decisively.

An agent is considered an independent problem solving unit which contributes to the whole solution (rational behavior) according to the local objective function (autonomy) (Müller 1993). For this purpose an ideal agent consists of several problem solving levels. The various problem solving levels apply different methods to solve the sequencing problem (see Figure 2).

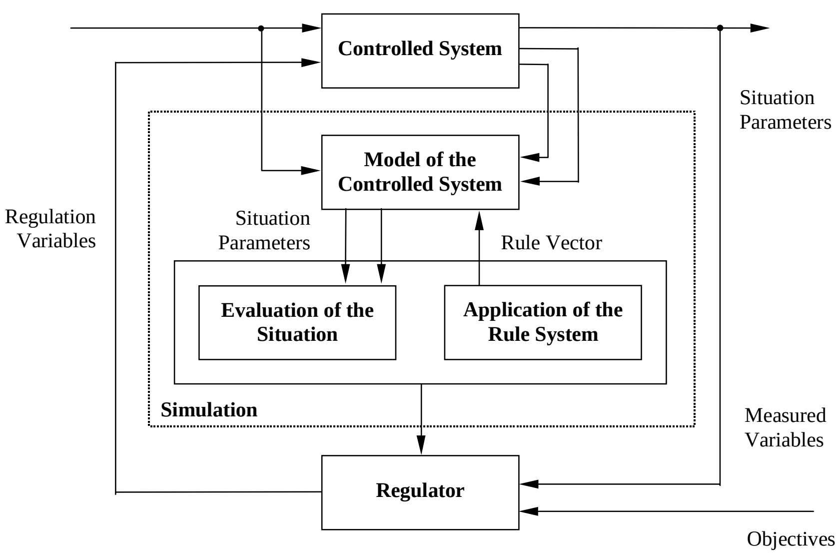

Figure 1: Representation of the General Solution

The lowest level shows a reference of the agent to the real system.

The objective of the local problem solving level is to determine a preliminary order sequencing based on the local target criteria of the agent.

Now, there is a possibility to improve the local decision by including global aspects. The global problem solving level consists of two layers. The interaction layer has the task to determine possibilities to improve the local solution by communicating with other agents. The job of the coordination layer is to decide which of the incoming inquiries is the one to fulfill the global objective function best.

4 DESCRIPTION OF THE PROBLEM SOLVING LEVELS

4.1 The Local Problem Solving Level

The analysis of the specific production conditions in the semiconductor industry (see section 2) pointed out that the application of priority rules does not entirely suffice for solving the sequencing problem.

Therefore the local problem solving level uses a rule based component, called the RBD-Component (Rule Based Dispatching Component) which consists of hierarchically structured criteria and rule systems. The RBD-component aggregates three different hierarchies of criteria to a total priority for each charge (Thiel 1997). Each hierarchy of criteria refers to one or more production conditions (see Figure 3).

The differentiation of further hierarchies of criteria is oriented towards the objectives to minimize the variation of the due dates and the sequence dependent setup times and to maximize the workload of the charge. The aggregation of the individual parameters in hierarchies of criteria is rule-based. Each hierarchy of criteria indicates which contribution the charge can perform to fulfill the mentioned local objective.

Different local strategies can be realized by weighing the hierarchies of criteria differently. The weight of a criterion demonstrates the importance of this criterion and the associated production condition. So it is possible to realize both strategies to minimize tardiness and lateness of orders and strategies to maximize the throughput. A higher flexibility of the solution results from this.

4.2 The Global Problem Solving Level

4.2.1 Objective of the Usage of Interaction-and Coordination-Procedures

Local rules do not consider the interdependencies between production segments. Hence a "good" local sequencing can be found, but a summarization of "good" local sequences will not result in the optimal sequencing for the whole production line inevitably (Fowler 1992, Gurnani 1992, Holthaus 1993). Therefore the global problem solving level uses interaction and coordination processes to find a better solution. In this context interaction can be considered as the causal and lasting influence of one agent's condition by

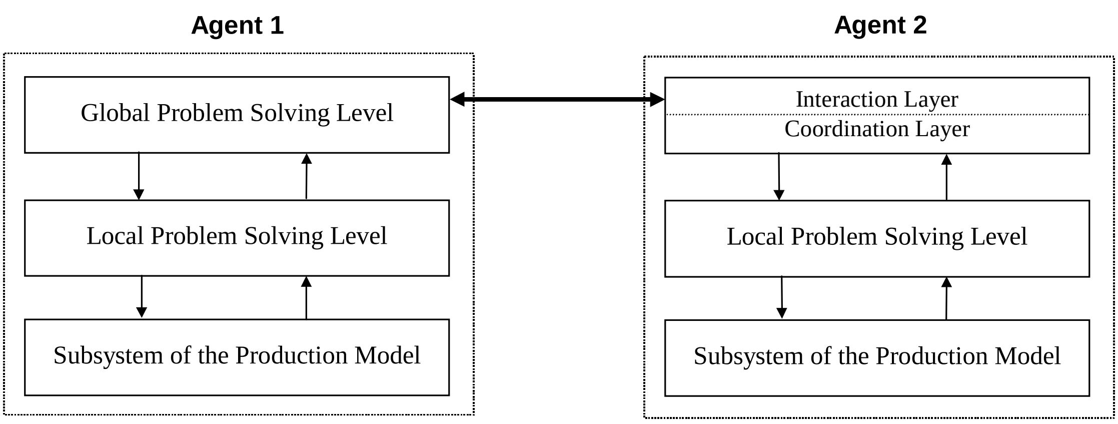

Figure 2: Architecture of the Solution

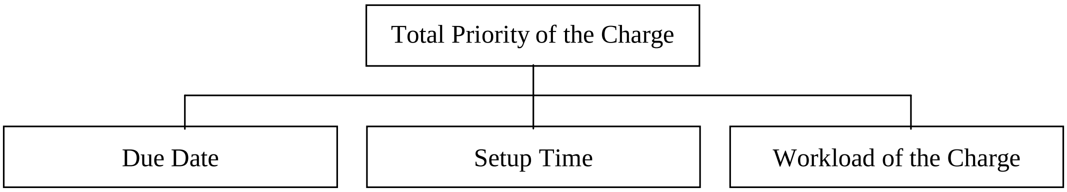

Figure 3: Aggregation of the Contribution of Hierarchies of Criteria to a Total Priority of the Charge

other agents. This interaction is necessary to solve certain manufacturing conditions (for example technological conditional times) and to achieve the best control for the global end limitations. Finally this is reflected in a better quality of planning.

The range of applications of interaction and coordination procedures derives from the following objectives:

- maximization of the utilization of the charge
- maximization of the capacity utilization
- minimization of the amount of setup times
- minimization of the waiting times
- minimization of the transgressions of conditional times

4.2.2 Coordination of Different Inquiries at One Agent

An essential unsolved problem by applying interaction methods is the decision on realizing the arriving inquiries (Holthaus 1993).

When inquiries arrive at a production segment there are two tasks:

1. to evaluate the inquiries by means of local and global criteria
2. to decide whether inquired tasks should be realized or not.

When a production segment receives such an inquiry, its agent must transfer this inquiry onto the local problem solving level. Based on the local objective criteria, this level determines the change of its own benefit the realization of the inquired task would cause. The global problem solving level of the adjacent agent compares the given growth of benefit to the benefit of the requesting agent. Only the inquiry with the highest positive total benefit is confirmed. All other inquiries will be canceled.

5 IMPLEMENTATION DETAILS

The tool "ManSim" from Tyecin Inc. has been used for the realization of the proposed production control solution. This tool is designed especially for use in the semiconductor industry and has an integrated simulation model. Only the needed data must be put in by a graphical interface. ManSim offers a programmer interface called "User Access" (see Figure 4). So it is possible to influence the simulation model on the base of events. There are events like "Event_Select_Lot" (selection of orders from the queue of a workstation when loading orders onto an equipment) or "Event_Done" (an equipment has finished the processing of orders). When such an event occurs in ManSim, the Tool will call C-functions that are attached by User Access. So the user has the ability to react to these events. For example, the selection of the order that should be processed next is possible.

6 SUMMARY

The answer to the dispatching problem in the semiconductor industry requires the integration of all production conditions in one solution. The realization of the requirements of an equivalent representation of the reality creates the assumption to get valid conclusions from the simulation-results to the real system. Thus the base for a realistic selection of an order sequencing is given. A model for simulation was developed that supports the order sequencing on a coarse and fine level. Within the scope of the coarse sequencing, a forecast of the due dates of production orders is supported. By way of contrast, the fine sequencing has to determine an efficient order sequencing in relation to the actual production situation and the given objectives. By integrating specific production conditions and market oriented demands in a model, the deficit of prior production control instruments could be nearly redressed.

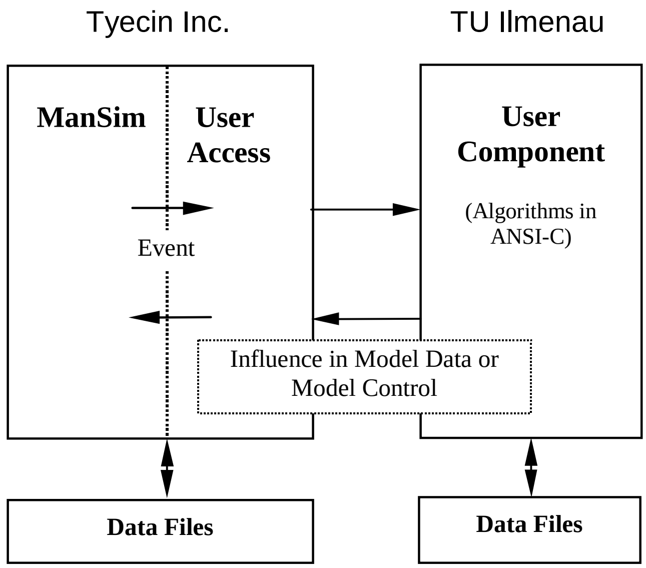

Figure 4: User Component Add-On for the Simulation System "ManSim"

REFERENCES

Fowler, J. W., Phillips, D. T., Hogg, G. L. 1992. Real-time of multiproduct bulk-service semiconductor manufacturing processes. In IEEE Transactions on Semiconductor manufacturing, Proceedings 5, Page 158-163.

Gurnani, H., Anupindi, R., Akella, R.1992. Control of Batch Processing Systems in Semiconductor Wafer Fabrication. In IEEE Transactions on Semiconductor manufacturing, Proceedings 5, Page 319-328.

Holthaus, O., Ziegler, H. 1993. Zur Koordination dezentraler Werkstattsteuerungsregeln. In Dyckhoff, H. u.a. (Hrsg.), Operations Research Proceedings 1993, Page 157-163. Berlin u.a

Kahlert, J., Frank, H. 1993. Fuzzy-Logik und Fuzzy-Control. Vieweg Wiesbaden.

Thiel, M. 1996. Entwicklung von konzeptionellen Ansätzen für eine flexible, simulationsbasierte Fertigungssteuerung auf der Basis einer Unternehmensanalyse. Diplomarbeit, TU Ilmenau.

Thiel, M., Schulz, R., Beyer, J. 1997. Simulationsbasierte Fertigungssteuerung bei komplexen Prozeß-bedingungen am Beispiel der Chipherstellung. In: Produktion als Dienstleistung - 10. Ilmenauer Wirtschaftsforum.

AUTHOR BIOGRAPHIES

PETER GMILKOWSKY is a University Professor in the Department of Business Related Computer Science I at the Technical University of Ilmenau, Germany. His research interests include manufacturing systems simulations and the control of production and logistic systems. He is a member of the Conference Board of Directors of the ASIM (Arbeitsgemeinschaft Simulation in der Gesellschaft für Informatik).

ROLAND SCHULZ is a Ph.D. student in the Department of Business Related Computer Science I at the Technical University of Ilmenau, Germany. His research interests include manufacturing systems simulations, distributed artificial intelligence and machine learning. He received a M.S. degree in Business Related Computer Science from the Technical University of Ilmenau in 1996.

MATTHIAS THIEL is a Ph.D. student in the Department of Business Related Computer Science I at the Technical University of Ilmenau, Germany. His research interests include manufacturing systems simulations and fuzzy rule-based expert systems. He received a M.S. degree in Business Related Computer Science from the Technical University of Ilmenau in 1996.

HOW TO CONTACT THE AUTHORS:

Please use the following E-Mail address:

matthias.thiel@wirtschaft.tu-ilmenau.de