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AUTOMATED MATERIAL HANDLING SYSTEM TRAFFIC CONTROL BY MEANS OF NODE BALANCING

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ABSTRACT

This paper presents a logistic algorithm that improves traffic conditions in a network-like automated material handling system (AMHS). The algorithm uses a look-ahead procedure and series of nodal parameters in order to balance the flow of traffic to and from load/unload nodes. In doing so, it helps manage, distribute and allocate free AMHS vehicles more efficiently. A simulation model of the algorithm, material control system and the AMHS was developed and tested on various types of semiconductor manufacturing facility layouts. The results of the simulated algorithm demonstrate up to 30% improvement in the AMHS lot delivery time.

1 INTRODUCTION

As a key step in the software development process, PRI Automation has employed the use of simulation modeling for testing algorithms and new features and optimizing software parameters. The use of simulation modeling has proven to be invaluable, especially in cases where the effects of new software enhancements may be disruptive to the total system. An accurate simulation model can give the developer the flexibility of assessing the total system output based on countless variations of an algorithm. In this paper numerous combinations of an AMHS controller algorithm have been tested on a variety of test cases in order to come to a solution for a specific problem.

A detailed simulator of the TranNet™ material control system (MCS) and AeroTrak™ AMHS has been developed and successfully employed in numerous design and verification projects. A unique software algorithm has been developed and modeled to resolve a material handling system traffic problem.

The automation of material handling in semiconductor fabs has proven to improve manufacturing operations through improved throughput, reduced direct labor, improved yield and improved work in process (WIP) tracking. AMHS in semiconductor fabs can be separated into two categories, interbay and intrabay. The focus of this paper is PRI Automation's interbay material handling system (AeroTrak). Essentially, the AMHS transports pods of production and test wafers (lots) from one bay to the next based on the information passed down to the MCS from the manufacturing execution system (MES).

One of the observed problems with the AeroTrak AMHS is that vehicles tend to cluster around one busy node at certain production times. This is a direct result of lot batching and frequent move requests at one specific node. Another contributing factor is the simultaneous traveling of loaded vehicles from various nodes to the same destination node. The said problem causes queuing of loaded and unloaded vehicles at a certain node. Which in turn may cause a traffic problem for downstream nodes and perhaps cause a vehicle gridlock.

A simple, but very effective, method has been developed and used in the past to resolve at least part of this problem. Each load/unload node is limited to one free vehicle request at a time. This has proven to work very well especially when there is lot batching. This method prevents the allocating and routing of multiple unloaded vehicles to one node. However, when there are multiple loaded vehicles traveling to the same destination node, there is no measure to prevent an unnecessary queuing at the destination node.

In this paper a measure has been introduced to balance the number of vehicles traveling to and from nodes in a way that distributes and allocates free vehicles evenly. This also incorporates a look-ahead measure before loading a vehicle and sending it to a particular destination. This is referred to as *Node Balancing*. Another measure has been introduced to monitor the total number of moves per node, regardless of inbound or outbound. This is referred to as the *Node Density*, which can be a ceiling of number of moves related to a node at one time.

The MCS is responsible for prioritizing and initiating move requests for the AMHS. TransNet MCS, developed at PRI Automation, contains an internal control algorithm that limits the number of move requests based on the current loading of the AMHS. The control system is a feedback method to assign a certain number of high priority moves, for example based on the due date of the lot, and to defer lower prioritized moves until a later time when there is less demand on the AMHS.

Although some kind of prioritization is taken into consideration when sorting through move requests, the MCS has no topological knowledge of the AMHS. Using the node balance and density data, the MCS will have another indicator to select higher quality jobs that help traffic conditions in the AMHS. This also helps to utilize AMHS vehicles more efficiently.

Subsequently, an algorithm was developed to use the balance and density parameters in an optimized manner. The balance-density algorithm is used by the MCS to qualitatively select move requests based on a balanced node and a given density per node.

The balance-density algorithm attempts to minimize the unloaded vehicle travel (moving to load) by looking ahead for a loaded vehicle destined for a node with a move request. Once the load onboard the vehicle has been delivered, the vehicle can be reallocated to pick up a load at the same node. This would be a preferred balance case. If there are no preferred balance situations, there are other steps that safeguard the on-time delivery of prioritized lots.

2 SIMULATION MODEL

A detailed simulator of the TranNet MCS and AeroTrak AMHS has been developed using AutoSimulation's AutoMod™ and successfully employed in numerous design and verification projects. The scope of this discrete-event simulator includes all physical components and the software logic of the integrated AMHS. The TransNet routing and dispatching rules were essentially replicated in the simulator. The rules were "translated" from the controller's C++ source code to the AutoMod process language. The simulator is a flexible and reusable tool for testing and evaluating AMHS layouts as well as controller algorithms.

The simulator basically models the production activity of each fab as it pertains to the material handling system. It is assumed that tightly integrated PRI Automation products (TransNet MCS and AeroTrak AMHS) are used as the interbay lot delivery system.

One of the benefits of developing an accurate simulator is being able to model software and hardware enhancements. PRI uses simulation to guide product development projects. The benefits of new products are assessed and enhancements to existing products are evaluated through simulation modeling. Moreover, simulation modeling has enabled PRI software development to test out various algorithms and measure their effectiveness prior to any feature enhancement.

Numerous combinations of balance and density parameters were simulated and parameters were found that work well on a variety of AMHS layouts and vehicle numbers. The results demonstrated that in most cases, the parameter of interest (transport time, delivery time, or lot lateness) was significantly improved while enhancing vehicle utilization.

3 METHODOLOGY

Three different types of layouts were considered for the simulation study. Each varies in the layout style, number of nodes, throughput (moves/hour) and number of vehicles required to complete the throughput. A summary of this information is presented in Table 1.

Table 1: Layout Characteristics

Number of	Case 1	Case 2	Case 3
Nodes	21	85	46
Throughput	150	350	150
Vehicles	12	50	33
Batching	No	No	Yes
Layout style	Center aisle	Ballroom	Two floors

Case 1 is a smaller system with relatively low throughput. Case 2 is a much larger system with higher throughput, and case 3 is a multi-level layout with large batch sizes (six lots).

As mentioned earlier, one of the major factors in the traffic congestion is the effect of batching. As a result of lot batching, the AMHS may dispatch multiple vehicles to one node and/or route multiple loaded vehicles to one node. In this paper, it is proposed that by looking at the list of events and tasks that are being completed or are soon to be completed, we can combine some of these tasks together. Here is an example such a situation:

Let's assume that a loaded vehicle is destined for node A and there is a move request at node A. The controller would allocate a free vehicle and route that vehicle to node A. At this point there are two vehicles destined for node A, one free and one loaded. Ultimately, there will be two free vehicles at node A within a very short time. We could avoid allocating the free vehicle by simply delaying the allocation, and allow the loaded vehicle to arrive at the node, unload, and then be re-allocated to the same node.

Such dispatch and allocation sequences can become very complicated when there are hundreds of events to sort through. The balance and density nodal parameters are intended to simplify the process. Also, an algorithm is designed to use the nodal parameters in a way that it optimizes the request selection.

The balance parameter is the difference between the number of moves going to and the number of moves leaving from a node. The density parameter is the total number of moves occurring at a node. In the Figure 1 example the balance and density parameters for node A are one and five, respectively.

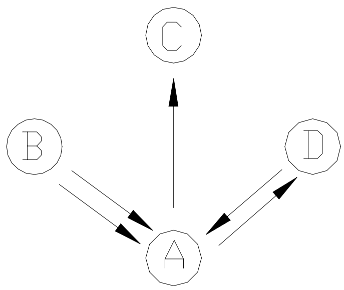

Figure 1: Example of Node Balance and Density

Through an iterative process, optimized numbers and combinations of the nodal parameters have been developed. These parameters were tested on various layout types to ensure repeatability of results.

The algorithm is based on an event driven process that tries to find the optimum move requests so that unnecessary free vehicle travel is minimized. Events such as a new move request or a vehicle becoming free trigger the search process. The algorithm matches move requests with vehicle destinations that meet or produce close to optimized nodal parameters.

4 RESULTS

A baseline simulation was built and run for each case. The baseline represents the current algorithm used in the software. The enhancements to the software are then measured by comparing the output of the simulation model with the new algorithm to that of the baseline simulation. The performance measures are AMHS mean delivery time ($\bar{x}$ DT), standard deviation of delivery time (s DT) and vehicle performance. Vehicle performance is directly related with free vehicle availability.

Table 2: Simulation Results

	Improvements over the Baseline		
Performance Measures	Case 1	Case 2	Case 3
$\bar{x}$ DT	30%	15%	14%
s DT	30%	37%	26%
Vehicle Performance	6%	11%	6%

The simulation results show that in three different cases mean delivery time and deviation from the mean improved significantly, as compared to the baseline. Also, free vehicles are more readily available due to the software enhancements. Mean delivery time and standard deviation improvements range from 14-30% and 26-37%, respectively.

5 SUMMARY

In this paper a logistic algorithm was presented that improved traffic conditions across three different automated material handling systems designed for interbay delivery for semiconductor manufacturing facilities. The systems differed by layout style, size, and throughput. The thesis of this paper is an algorithm that uses nodal parameters in order to balance the flow of traffic to and from load/unload nodes. A simulation model of this algorithm demonstrated up to 30% improvement in the AMHS lot delivery time.

REFERENCES

Gaskins, R.J. 1996. AeroTrak™ interbay transport simulator. PRI Automation White Paper.

Rivera, I. and T. Jefferson. 1999. Simulating the impact of automated material handling equipment availability in support of continuous improvement programs. *AutoSimulations Symposium '99*: 144-148. Salt Lake City, Utah.

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