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THE NEXT GENERATION OF MANUFACTURING SIMULATION

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ABSTRACT

Emerging manufacturing systems (FMS) pose a significant problem for traditional material flow and discrete event simulators. The decomposition level in the traditional paradigm is too coarse to provide adaptive process selection and cost-based routing. Also, increased complexity within the manufacturing work cell has reduced the accuracy and confidence level of the input parameters to the simulation, such as cycle times. Thus, the simulation paradigm for industrial material flow and manufacturing processes must be revised.

The focus of this paper is three-fold. First is an analysis of the problems facing the traditional manufacturing simulation methodology as a result of the new manufacturing techniques. Second is an explanation of the need for a continuous event, physically based workcell simulation functionality tightly integrated with a discrete simulation model that has been extended to properly handle the requirements for flexible processing and routing logic. Lastly, the paper addresses the future of factory floor simulation in the context of the emerging distributed control system of the FMS.

INTRODUCTION

Increasingly, emerging manufacturing systems are adopting complex and flexible automation equipment such as robotics, intelligent cell controllers and AGV's. Also, utilization of new techniques in inventory management (JIT), material handling (AGV's) and process scheduling (adaptive cost-function routing) are attempting to maximize flexibility, minimize cost, and reduce time to market. These efforts are in response to economic forces of the market which do not provide the luxury of time to fine tune the manufacturing process on the floor since the economic life span of the product is getting shorter. As a result, reliable simulation of flexible systems is a growing priority.

Numerous traditional software simulation tools are available for the design and analysis of manufacturing systems. These software tools may be divided into two basic groups: Discrete Event Simulators such as those for material flow, and Continuous Event Simulators, such as workcell simulation for off-line programming. Discrete Event Simulators are characterized by a wide scope, often modelling large segments of a factory, and address the logical relationships and average properties of the system. Workcell simulators, on the other hand, have a narrow focus on a particular machine or group of devices in a workcell. The simulation is physically detailed, with collision detection, I/O signal simulation, and dynamic motions for moving devices such as robots. Theoretically exact motions and time quantities are considered. Workcell simulators are currently enjoying success in process visualization and off-line programming tasks.

THE PROBLEM

The requirements for simulation of the flexible manufacturing system are beyond current, commercially available simulation systems. For the discrete event simulator, there are two principle areas of weakness. The first is the inherent assumptions made for process cycle times, and the second is a lack of flexibility in the modeling system to reflect the behavior of modern manufacturing systems. The second weakness is manifested on many scales. Setup procedure variations, adaptive (cost based) routing, and large scale paradigm flexibility such as push vs. pull production are all difficult to simulate confidently with traditional tools.

As individual workcells become more intelligent and complex, often with multiple interacting pieces of automation equipment such as robots, the ability to estimate the time required for a particular process becomes fraught with uncertainty. The traditional notion of a workcell cycle time is insufficient for a system that may perform a host of processes, depending on real time production schedules and available part mix. There is a need to simulate meaningful setup and takedown times considering variations due to previous and next processes, and state factors such as color changes, and so on. Specific details of the equipment and the process may significantly alter the time required for the total transaction, and particularly, interaction effects are difficult to predict, even for automation engineers. Typically, such effects are revealed during actual device programming on the factory floor, long after decisions have been based on a simulation model with faulty assumptions

At larger factory scopes, request-driven, or "pull" production techniques (used in flexible system to minimize inventory) are difficult to simulate without writing the entire simulation in a sufficient simulation language. Particularly, a mixed simulation of push and pull production poses significant difficulty for simulators with fixed or minimally flexible processing logic, while this activity is especially important during the conversion of a traditional factory to a Just-In-Time system.

Lastly, the standard client-server model for material flow simulators is unable to properly model the behavior of flexible workcells that make process and routing decisions in an adaptive manner, on line. Many flexible manufacturing control systems may minimize a cost function when deciding which of several machines a given part should go to receive its next processing operation.

Essentially, the complexity and distributed intelligence of emerging systems is beyond the capacity of traditional material flow simulators since their focus is too wide. The recent evolution of workcell simulators does provide a technology capable of modelling these complexities, but it is not available at wide scopes like the factory floor, largely due to computational limitations. As a result, a designer must utilize different, independent, and incompatible packages to achieve a reasonable level of simulation confidence. Furthermore, the simulation/animation models must be recreated and edited separately in the different packages.

SOLUTION

The simulation paradigm for industrial material flow and manufacturing processes must be altered. There are two principle aspects that need to be addressed:

1. Workcell simulation technology must be adopted as a proper stage of a material flow analysis to provide a detailed physical, continuous event simulation. This delivers process verification and accurate cycle times for each process executed by the flexible cell. Simulating the process in detail clarifies the logical time dependencies for setup and takedown, and this knowledge may be used in an appropriate material flow simulation.

2. This activity must be tightly integrated with an improved model for the material flow problem which can accurately reflect the behavior of emerging flexible systems. It must be possible to embody flexible processing, routing, pre-emption, and failure logic in order to use knowledge gained in the workcell simulation. Push and Pull process simulation must be available.

Workcell simulation technology is maturing; it is now possible to perform a detailed physical (dynamic) simulation of complex manufacturing workcells that utilize flexible equipment such as robots, vision/tactile sensors, intelligent multi-axis milling machines, and combinations of hard and soft automation equipment. This technology is currently growing rapidly in process visualization and off-line device programming roles. It can provide high confidence cycle times for a given process, taking into account the need for collision free operation and the physical limitations of the automation equipment. Often the simulator may reveal that a planned process is indeed impossible within the given constraints, and other alternatives must be explored, including workcell fission, the adoption of faster robots, and so on. Thus, the workcell simulator can confidently deliver process verification as well as accurate cycle times. This in turn directly affects the quality of the discrete simulation, whose assumptions have now become confident predictions. Furthermore, in an integrated system, the detailed physical modelling provides an animation base that can be automatically used by the discrete simulation for visual comprehension and presentation.

Internally, the material flow simulator must provide user-defined processing and routing logic in order to accurately model the behavior of flexible workcells. Control systems for flexible factories are converging on a distributed methodology where processing, scheduling, and routing decisions are made by a network of computers connected via MAP/TOP communication systems. Thus the simulation system must exhibit decentralized decision making, based on the system state. Simulation analogies for vision systems, tactile sensors, and intelligent task planners must be adopted. These must be available to the user in the form of environmental queries for information in a manner that reflects the way actual cell controllers and adaptive scheduling algorithms perform on the factory floor. Based on information gathered on the spot, the process or routing logic can make intelligent decisions, and find minimum-cost paths. Cost functions may be based on distance, queue depths, and machine utilization considerations. For example, a high precision mill is a scarce resource, and thus a low precision operation might be routed to an available low precision mill even if it takes longer.

CONCLUSIONS

In the near term, it is essential for factory floor simulation systems to combine discrete and continuous simulation technologies and apply them to the appropriate domains. It is also necessary to expand the client-server paradigm to provide significant decision making abilities within the server entity, and thereby achieve a more accurate emulation of the distributed FMS control system. These techniques then need to be bound together in a tightly integrated system that allows utilization of the information gathered at both the factory floor level and the detailed workcell level, minimizing model redundancy.

As the evolution of the FMS continues, particularly with regard to the control system, it can be seen that the simulation paradigm must keep up. Ultimately, the simulation system is a recreation of the actual factory control system. Control software ideas presented by Naylor and Voltz indicate that the distributed nature is transparent to the program metaphor, and thus can execute on a single processor as readily as a network. Given this, the ideal simulation system is actually the FMS control system itself, with only the physical hardware at the workcell level in need of simulation. If the simulation interface to the control system is complete and bi-directional (implying accurate simulation of sensors, etc.), then the factory control system would be unable to distinguish between controlling the actual factory of workcells, and controlling the simulation of those workcells. Given sufficiently accurate (physical) workcell simulation, there are then no assumptions in the factory floor simulation, and simulation reliability and confidence approach unity.

REFERENCES

Dyck, Harold, Johnson, Richard A., and Varzandeh, Jay (1988). Transforming a Traditional Manufacturing System into a JUST-IN-TIME System with KANBAN. Proceedings of the 1988 Winter Simulation Conference, pp. 616.

Fuller, Charles E. (1988). An Introduction to Workcell Simulation. Presented at the SME Conference for Successful Planning and Implementation of Flexible Assembly System. Available from SME.

Ketcham, Michael G. (1988). Simulation Modeling of JUST-IN-TIME Assembly Systems using an Information-Based Methodology. Proceedings of the 1988 Winter Simulation Conference, pp. 624.

Ketcham, Michael G. and Krishnaswamy, Chandrashekar (1988). A Generic Simulator for Continuous Flow Manufacturing. Proceedings of the 1988 Winter Simulation Conference, pp. 609.

Naylor, A. W. and Voltz, R. A. (1987). Design of Integrated Manufacturing System Control Software. IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC-17, No. 11, Nov.-Dec. 1987, pp. 881-897.

Noche, Bernd (1986). Simulation in Material Flow System -- Trends and Developments. 1986 Annual Simulation Synposium, pp. 11.

Prasad, Kowdle and Rangaswami, Madhav (1988). Analysis of Different AGV Control Systems in an Integrated IC Manufacturing Facility, using Computer Simulation. Proceedings of the 1988 Winter Simulation Conference, pp. 568.

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