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A CONCEPTUAL DESIGN FOR SIMULATION IN A REAL TIME CONTROL TOOL

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ABSTRACT

This paper discusses the use of simulation as an evaluation technique within an automated or semi-automated real time control system. Within this control system, simulation will be used to play out possible scenarios emphasizing various objectives of system control. The simulator will be, as much as possible, a deterministic model utilizing factory data bases to more accurately forecast results. The structure of the simulation model, including typical inputs from appropriate data bases, will be detailed.

As a result of including a simulation model in the control system, an evaluator would examine the simulation outputs. This evaluator can be automated, human or a combination of the two. Through the control system, this evaluation would then be employed to direct the physical system. An ideal application of this approach is in the manufacturing environment. The advent of automated and computerized equipment makes the implementation of an automated control and evaluation system a feasible and practical enhancement to a manufacturing system.

This paper will discuss the authors' thoughts on how such a control system could be implemented and what form it would take. Special emphasis will be given to the structure of the control system. The structure of the system will include description of the actions and interactions of appropriate factory data bases, the simulation model, evaluation criteria and the physical scheduling or control of the system. The overall control structure will be detailed as an integrated system. Different roles or utilizations of human interfaces will also be investigated. The final discussion will include an analysis of an implementation environment and a suggested implementation strategy.

1.0 Introduction

Simulation is not a new dimension in manufacturing. Models and languages are available to study inventories, distribution and warehousing strategies, and product mixes (1,2,3). Simulation has also been used for some time in analyzing work flows, bottlenecks, and alternative solutions to these types of manufacturing problems in flow shops, process shops, and job shops (4,5,6). However, the use of simulation as a real time control tool is relatively new to manufacturing. This paper will outline the use of simulation as a real time control tool. Within this concept, system simulation would work to make the controller 'smart' by giving it the ability to evaluate control strategies before they are implemented.

This paper will document a typical structure within manufacturing that can employ simulation within the control strategy. The logical factory data base connections will be constructed. In addition, the systems necessary to integrate simulation into the control structure and have it employed as a viable tool will be outlined. Typical environments where this type of control strategy may be implemented will also be described. Finally, an outline of how such a control system could be implemented and the form it would take will be presented.

2.0 Why Simulation?

Many manufacturers today have or soon will implement sophisticated, computer controlled manufacturing systems. These systems can include numerical controlled machines, robots, automated storage and retrieval systems, etc. Integrating these separate computer controlled systems into one large control system where each component works in conjunction is now a possibility. This integrated controller works on-line with the complex manufacturing system to provide quick feed-back or real time control.

Future steps are being taken to include simulation in the integrated control system. This inclusion gives the control system the ability to evaluate its own instructions before passing them to the manufacturing system. The simulator will play out the operation of the manufacturing system using the control system's instructions before the instructions are directed to the manufacturing system. With this approach the simulation outputs can determine the effectiveness of the control instructions and identify any problems the instruction may cause if implemented by the manufacturing system. Following the initial execution of the simulation, the control instructions can be accepted, or altered and re-simulated.

2.1 The Simulation Model

The simulation model within the control system should accurately replicate the workings of the physical manufacturing system. The model will be discrete and will simulate the movement and processing of the parts in the manufacturing system. The model will be populated to represent the parts that are currently in the manufacturing system. The model will also account for the resources in the manufacturing system. Availability of the equipment including maintenance will be modeled. This type of information will be available from the factory information data bases, detailed in Sections 3.1 through 3.3.

The model will receive as input a factory floor schedule, typically orders and the sequences in which they are to be processed by the manufacturing system. The model will produce measures of effectiveness of these control instructions. These measures can include manufacturing system throughput, resource utilization and order lateness. After these measures are predicted by the simulation model and evaluated, the control instructions are accepted and implemented by the manufacturing system or the control instructions are altered and re-simulated.

3.0 The Structure of the Control Model

The overall structure of the control system is pictured in Figure 1. This is a structure adapted from previous work outlined by Duket & Pritsker (7).

The factory information data bases include an Order Data Base, a Resource Capicity Data Base, a Scheduling Rules and Constraints Data Base and a Work-In-Process Data Base. These data bases will 'drive' the system with their information flow. They will determine existing conditions and interface these conditions with demands and constraints in order to create the schedule to meet the objectives of the company. The company objectives will be reflected in the control system by the scheduling and evaluation procedures and the operator interfaces. Following is a general description of the structure of the control system and how it functions as an integrated entity.

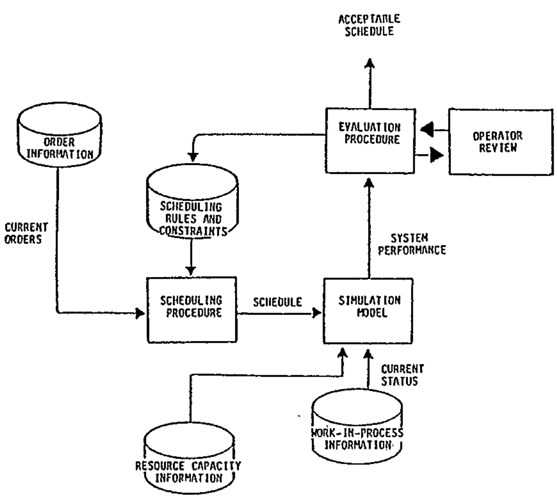

Figure 1. The Structure of the Control Model

3.1 The Order Data Base

The Order Data Base will contain the information necessary to produce parts. This type of data will include key information such as part number and order number. The part number references back to process planning which provides the routing of the part through the system along with the standard times allowed for the part in each stage of the process. It will also provide any machine data necessary to make the part on numerical control machines and the inspection data necessary to verify the correctness of the part. If the control system resides in a more manual environment, the part number will provide references to the procedures necessary to make the part--whether they be assembly procedures or fabrication procedures.

The order number will reference order information such as the start date of the order in each working area assigned by the process plan. The quantity of the part to be produced will also be part of the order information along with when and where the inspections on the part during the process should occur.

The Order Data Base contains the current orders in the system and some finite capacity for future orders that are to be released to the system during some future horizon (one to two weeks). The Order Data Base will provide the scheduling procedure with the current planned orders, due dates of the orders and the priority of the orders (if more than just a function of the due date).

An additional function of the Order Data Base will be to track past history (performance) on orders and report discrepancies (actuals vs. standards) to the appropriate manufacturing function. This is an important part of the system as the simulation model will be forecasting manufacturing on standard times and the accuracy of the model will be impacted by the accuracy of the times used.

3.2 The Resource Capacity Data Base

The Resource Capacity Data Base provides the Simulation Model with the capacity of the system in which the orders will be processed. This information will include machine capacity and availability, manpower availability and capability, and alternate acceptable manufacturing processes (if applicable).

The resources available to manufacture an order are usually serial in nature (in a flow shop) or centrally located (in a job shop). Different production processes may use some of the same resources and must compete for these based on the priority of the order. From this information and information from the Order Data Base, the Simulation Model will be able to analyze the loading of the system over the order horizon to examine the meeting of schedule and priorities. In a job shop the Resource Capacity Data Base will describe the processes used for the order and any alternative processing available to the Simulation Model.

3.3 Work-In-Process Data Base

The Work-In-Process (WIP) Data Base will provide the Simulation Model with an updated 'snapshot' of the existing work in the system. This information will include the status of work orders (how many pieces are through, how many are left, what stage of the process they are in, and so forth). Also included will be the status of the resources (what people are currently working, what men and machines are available, and so forth), and the updated priority of the order.

The WIP Data Base is intended to complement the Order Data Base by giving detailed information on the current jobs in the system while the Order Data Base gives the history of these jobs. When a job finishes one of the specified sequences, the WIP Data Base updates the Order Data Base with the appropriate data.

3.4 Scheduling Rules and Constraints

The Scheduling Rules and Constraints module of the control system must serve two basic functions. In the first case it serves as source of user supplied requirements to the scheduling procedure. These may include the relative importance among order due date, equipment utilization and part throughput. These rules and constraints are initially set in accordance with the objectives of management.

The second basic function of the Scheduling Rules and Constraints module is to direct future analysis if the evaluation procedure does not accept the current set of control instructions. In some cases this may simply be the alternation of the relative importance factors that are associated with order due date, equipment utilization and part throughput. In other cases this may be the initiation of a heuristic that alters order by order the previously simulated schedule. The first approach concerning relative importance factors for the inputs to the scheduling procedure is preferable. This approach is more generally applicable to all kinds of manufacturing and is flexible enough to follow changing management objectives.

This type of Scheduling Rules and Constraints module is a typical example of what is known as an "Expert System". The application of Artificial Inteligence in scheduling is an emerging technology and will be seen more and more as the methods mature.

3.5 Scheduling Procedures

The Scheduling Procedures employed by a control system will vary depending upon the objective of the manufacturer. Scheduling jobs by their due dates or some function of due dates (i.e., critical ratio) are typical of batch and job shop manufacturing while flow shops may schedule jobs to maximize throughput or machine utilization. It is also not unusual for a single firm to use various scheduling philosophies depending upon different environments within the firm. However, scheduling jobs, especially in a batch manufacturing environment is more complex than the application of one or more of the classical sequencing rules.

The effective scheduling of jobs depends on more than an initial sequencing. In scheduling jobs through a manufacturing area, the typical shop floor supervisor will take many different 'system' variables into account when he receives his ordered list of jobs to accomplish. These system variables include the availability of the resources necessary to do the job (men, machines, tools, fixtures, cutters, process planning, material and so forth). The possibility of reducing set-up time by sequencing like tasks is another variable that may also be included. The experience of the people performing the tasks may also be a factor taken into account.

How do all these variables--some of them critical in meeting scheduling objectives--get included in the decision making process in a real time control system? The authors contend that the utilization of simulation combined with the effective integration of a decision methodology based on the many system variables is the piece missing from effective real time control.

3.6 Evaluation Procedure

The evaluation procedure of the control system must examine the outputs of the simulation analysis and determine if the control instructions are acceptable and should be implemented by the manufacturing system. The evaluation procedure may be totally automated, totally operator controlled or a combination of automated and operator controlled. For most U.S. manufacturing environments today it is recommended that a combination of automated and operator controlled be employed. Within this type of evaluation procedure the automated system will perform an initial analysis giving the operator the final approval or disapproval. In addition, the operator will play a part in the selection and importance of the performance measures and evaluation criteria.

The evaluation procedure will compare the performance of the simulated system against a set of performance criteria. These performance measures and criteria that will be compared are highly dependent on the physical system and the objectives of the management of the manufacturing system. One specific performance measure (i.e., part throughput) may not be the only evaluation criteria. A combination of several performance measures (i.e., part throughput, order lateness, and resource utilization) may be included in the evaluation procedure.

When more than one performance measure is included in the evaluation procedure, it is likely that the performance measures will be weighted and the sum of the weighted performance measures will be compared to the performance criteria. The weighting factors for the performance measures as well as the performance criteria are dependent on the objectives within the control system.

In addition to the evaluation of the performance measures, the evaluation procedure must select the present control instructions or trigger the generation of new control instructions for simulation and evaluation. If the evaluation procedure identifies the schedule as acceptable, the control instructions are implemented by the manufacturing system. If the schedule is not found to be acceptable, inputs for altering the schedule are directed to the Scheduling Rules and Constraints Data Base.

4.0 Installation Environments and Implementation

The installation of a simulation model as a real time control tool may be accomplished in many different types of manufacturing environments. However, the level of success of the simulation model in a control system is a function of the environment. For example, the highly automated environment is typified by fairly advanced computer systems and data bases. The integration of simulation into this type of environment will have a higher success rate due to the accuracies of the data utilized within the model (automated systems have more predictable process times than manual ones). These types of manufacturing tend to be process (chemical, petro-chemical and the like), and modern manufacturing (automated assembly lines, flexible manufacturing systems and so forth). Unfortunately, most manufacturing is not process or highly automated. In a semi-automated environment, care should be taken to assure the integrity of the data used in the simulation model.

The implementation of a simulation model in a real time control system is also a function of the manufacturing environment. Most automated or semi-automated systems have existing data bases such as the ones previously described. However, most systems do not have a sophisticated Scheduling Rules and Constraints module--this is usually a function of the shop floor supervisor. It is possible that an expert "operator" (detailed as the Operator Review in Figure 1) may act as the Evaluation Procedure and the Scheduling Rules and Constraints module while these modules are under development. In this manner, the effect of the Simulation Model and the design of the other procedures are integrated into the system utilizing feedback from the use of simulation within the control system.

5.0 Conclusion

The use of simulation in a real time control system is relative new to manufacturing. Its successful application depends upon the degree of automation within the manufacturing environment and on the information data bases available. However, with the present push towards the integration of factory data bases and further automation and control with this data, the use of simulation to help predict outcomes and anticipate and avoid problems is the next logical step in real time factory control.

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