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Decision-Making Problems for Shop Floor Simulation in Discrete Part Manufacturing

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Abstract

Shop floor control systems (SFCS) are used to make real-time planning and scheduling decisions to optimize the efficiency of manufacturing shops. These shops exhibit a non-linear, dynamic evolution caused by 1) the concurrent flows of disparate parts following complex routings, 2) a variety of machines that breakdown at random times, 3) stochastic arrivals of new parts with different priorities, and 4) jobs that have probabilistic processing times and transportation times. Because of their ability to capture that evolution faithfully, simulation models are often used in the aforementioned decisions. In this paper, various types of decision-making problems encountered in a shop floor have been investigated and categorized into process related problems and resource related problems for shop floor simulation.

Keywords: Simulation, Shop Floor Control, Process and Resource models, Decision-making problems

1. Introduction

Shops involved in the fabrication of discrete parts typically have a software system that must be able to plan, schedule, monitor, and control various machining and material handling devices. That system, called the shop floor control system (SFCS), does this through a series of decisions that 1) ensures the completion of production orders and 2) optimizes one or more performance measures. In particular, once it receives the process plans for the parts to be produced, decisions are made based on route selection, resource allocation, workpiece scheduling, instruction downloading, process monitoring, and error recovery [Cho, 1993].

Simulation has been used to support these decisions because it can model and analyze systems, like a manufacturing shop, that operate in an environment that is highly dynamic and unpredictable.

In the simulation of the SFCS, there are three application areas: 1) Decision-rule validation/verification for planning and scheduling, 2) Analysis of resource-related changes such as resource layout, addition and removal of resources, resource properties, etc., and 3) Analysis of part-related changes such as the number and kinds of parts, inter-arrival time of parts, changes of process plans, etc.

2. Related Works

Various types of decision-making problems in SFCSs have been investigated. The scheduling problems encountered in a shop floor can be categorized into several distinct types encompassing a wide range of resources including parts, robots, machines, and AGVs. Different scheduling problems are categorized and sets of dispatching rules to each problem was applied in an effort to evaluate the impact of various rules on the system performance [Stecke et al., 1981].

Scheduling and dispatching rules for AGVs were examined and six scheduling problems associated with one particular system were defined [Drake *et al.*, 1995]. Design, planning, scheduling, and control problems were described in the context of flexible manufacturing systems [Stecke, 1985].

The impact of a “good” schedule for a particular decision-making problem and the effect of any one dispatching rule have been found to vary with several factors such as system layout, system state, and the desired performance measure [Cho *et al.*, 1993][Jones *et al.*, 1995]. These decision-making problems can be classified into process-related problems and resource-related problems and then several rules are provided in this research to resolve these problems.

3. Decision-Making Problems in Discrete Part Manufacturing

We reviewed all the decision-making problems encountered in a SFCS and then classified them into the two groups according to their characteristics: 1) process model-related decision rules and 2) resource model-related decision rules as shown in Figure 1. We discuss the definitions of the problems in this Sections. To resolve each decision-making problem, a decision-making rule can be selected and applied by the user.

Problems encoded in the Process Model	**Problems encoded in the Resource Model**
Process sequence problem	Part selection problem in a machine
Path selection problem	Transport selection problem
Resource selection problem	AGV location problem
Part buffering problem	Part selection problem in an AGV
	Robot location problem
	Part selection problem in a robot

Figure 1. Classification of process and resource-related problems

Two decision problems are possible at in every process step in the process plan: resource selection and part buffering. If alternative resources are specified for a process, the simulator must choose a primary and secondary resource set from the resource database. This is done using user-specified rules such as minimum processing time, minimum transport time, or minimum waiting time. For example, if the minimum-transport-time rule is selected, the simulator engine selects the machine tool located nearest to the current part's location.

The part-buffering problem is associated with the determination of the next destination for the part when no resource specified for the next process is available. In that case, the simulator engine may (1) send the part to the buffer, (2) let it stay at the current location, or (3) send it to the material handler. An exemplary rule used to select one of the options is the ratio of remaining time to total machining time of the next process -- if this ratio is larger than a pre-specified value, the part can be moved to the buffer. Figure 2 illustrates the sequence of rules fired when the simulator engine has already finished process P1 and examines the next process P2.

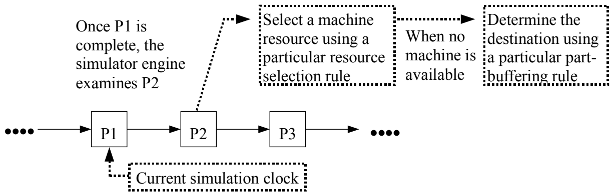

Figure 2. Sequence of fired rules after process P1 is
finished

The AND junction (A) means that all the processes between the starting A and ending A must be performed. In Figure 3a, processes P1, P2, and P3 lie between AND junctions. All of them must be done -- three of the six possible sequences are shown. The manufacturing efficiency, which is a function of setup time, tool changes, and fixture changes, will depend on which of these is selected.

The OR junction (O) means that one and only one of the processes or paths between the starting OR and the ending OR junctions should be selected and then executed. In Figure 3b, there are two possible choices: P1 followed by P2 or P3. Realistic process models will contain many such junctions, some of which will be nested. Consider Figure 3c. The correct interpretation is that P1, P2, and one of P3 or P4 must be done. Several possible sequences are shown in Figure 3.

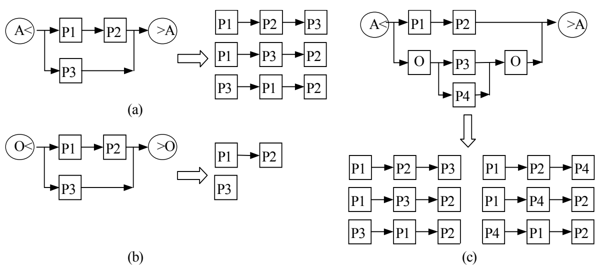

Figure 3. Examples of serialization of the processes
surrounded with junctions

When the simulator engine hits the initial AND junction, it does not immediately sequence all of the ensuing nodes. Instead, it chooses only the next node in the sequence. It does this one-at-a-time selection until the final AND junction is reached. This procedure, called the process sequence procedure, uses both the current state information and the rules imbedded in the definition of an AND junction. For example, if the rule is "minimum traveling time", then the process selected is the one to be executed on the machine located nearest to the current location.

When the simulator engine encounters an initial OR junction, it prioritizes all of the possible paths or processes, then selects the one with the highest priority. This procedure, called the path selection procedure, is also based on the current state and the rules imbedded in the OR junction. For example, the maximum-flexibility rule will select that path with the largest number of AND junctions, because that path has many processes that can be sequenced later. .

The transport selection problem is to determine the transport path and all required transport resources needed to move the part from its current location to its next location. A path is chosen from the available candidates identified from the directed graph. The choice is made using the imbedded rules such as "Minimum transport time" or "Non-busy transport". The part selection problem is to choose the next part to be processed from among those waiting in the buffer or other storage locations.

Many rules can be used for resolving the part selection problem, such as "Minimum processing time", "Minimum transport time", "Earliest due date", or "First in, first out". Figure 4 illustrates the procedure for part selection.

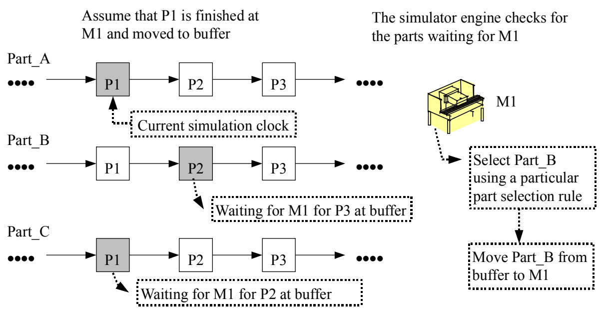

Figure 4. Conceptual situation of the part selection problem

4. Conclusions

. In this paper, various types of decision-making problems encountered in a shop floor have been investigated and categorized into process related problems and resource related problems for shop floor simulation. In particular, the simulator engine can utilize the decision-making rules to solve various decision-making problems associated with the processes and resources.

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