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INTRODUCTION TO MANUFACTURING SIMULATION

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ABSTRACT

This introductory tutorial presents an overview of simulation to manufacturing design and scheduling. A review of the modeling considerations in both application areas is provided. Finally, a number of example applications will be presented to illustrate the concepts.

1 INTRODUCTION

This introductory tutorial presents an overview of manufacturing simulation. The tutorial discusses the application of simulation in both manufacturing design and scheduling. We begin by examining the traditional application of simulation in manufacturing system design and the critical modeling features for typical manufacturing applications.

2 SIMULATION FOR DESIGN

Manufacturing simulation has been one of the primary application areas of simulation technology. It has been widely used to improve and validate the designs of a wide range of manufacturing systems.

2.1 Manufacturing Simulation Applications

Manufacturing applications include both facility design, as well as enterprise-wide supply chain modeling. The typical manufacturing model is usually used either to predict system performance or to compare two or more system designs or scenarios.

Facility design applications may involve modeling many different aspects of the production facility, including equipment selection/layout, control strategies (push/pull logic), material handling design, buffer sizing, dispatching/scheduling strategies, material management, etc. Depending on the objectives of the study, a detailed model of a facility level process can be very large and complex.

Supply chain models are used to study an enterprise-wide process that may encompass multiple production facilities, distribution centers, transportation systems, etc. In supply chain models the, individual plants are often modeled as simple capacity constraints on production units. Typically, these models are very large and data intensive.

2.2 Manufacturing Modeling Features

Manufacturing simulation models can be developed using both general-purpose and manufacturing-focused tools. However, depending on the complexity of the system being modeled, manufacturing focused tools can significantly simplify and quicken the modeling process. In this section, we will review some critical modeling features for typical manufacturing applications.

There are many different manufacturing-oriented simulation packages on the market and each has its strengths and weaknesses. Some packages focus on ease of use and compromise flexibility, while others focus on flexibility and are more difficult to use. Because most manufacturing systems have some unique intricacy, the best packages allow the user to combine easy-to-use constructs with more flexible, lower level constructs. There are some packages that are particularly good at representing material handling or some other aspect of manufacturing processes. Simulation packages also differ in their support for both input and output data analysis. Some of the more popular manufacturing-oriented packages include Arena, AutoMod, ProModel, and Witness.

When preparing to perform a manufacturing study, there are a number of common system features that are included in the simulation model. These topics are described and discussed below.

2.2.1 Resources

Most manufacturing systems comprise resources, such as equipment, labor, and material. The availability of resources is typically defined by shift patterns and/or the production, arrival, or consumption of material. Resources are also often grouped together and selection rules used to allocate resources from these groups to perform work. In many cases, the same resource might in multiple groups. The ability to flexibly model resources and resource groups along with their corresponding shift and breakdown patterns is a key requirement in most manufacturing applications.

2.2.2 Material Handling

In many cases, the material handling devices in the system significantly affect the performance of a manufacturing process. These devices include AGV's, conveyors, overhead monorail systems, etc. In general these are complex systems to model, and built-in material handling modeling constructs are required to accurately represent them.

2.2.3 Control Logic

In a typical manufacturing system, a job moves from workstation to workstation. The control logic for managing this movement through the system can be based on push logic, pull logic, or some combination. Special modeling features are required to accommodate each class of control logic. Within each class, additional flexible constructs are required to represent the specific details and exceptions of the lower level control logic.

2.2.4 Workstation Logic

The processing of work at a workstation typically involves multiple phases (e.g. setup, processing, teardown). Additionally, each phase may require a different set of resources. Workstation logic may also include concurrent processing and transfer batching between workstations.

2.2.5 Buffers

In many manufacturing systems, buffer space is limited and is a critical bottleneck in the system. A full output buffer can block the associated workstation and a full input buffer can block upstream workstations.

2.2.6 Orders/Process Plans

In many systems, each part type may follow its own process plan through the facility. This plan defines the routing and related information for processing the order. Process plans can vary from simple, straight-line sequences to complex networks involving subassemblies and parallel operations.

2.2.7 Job/Workstation/Resource Centric Data

There are several different ways for defining the processing data (processing times, resources required, etc.) within a manufacturing system. In job shops, the processing data is often a property of the job process plan. However, in a flow shop, this same data may be a property of the workstation or of the selected resource. Many systems combine these job/workstation/resource data representations. In this case, the processing data is distributed between the process plan, workstation, and selected resources. It is important that any modeling tool be able to represent the multiple types of data structure that occur in the various data models of the system.

2.2.8 Reports

The process of interpreting the simulation results from a manufacturing model is similar in most ways to any other type of stochastic model. However there are special manufacturing-focused reports that may be required. Important elements of these reports include both facility metrics and job processing time and cost data.

3 SIMULATION FOR SCHEDULING

Although simulation has traditionally been applied to the design problem, it can also be used on an operational basis to generate production schedules for the factory floor. When used in this mode, simulation is a Finite Capacity Scheduler (FCS) and competes with other FCS methods, such as optimization algorithms and job-at-a-time sequencers. However, simulation-based FCS has a number of important advantages that make it a powerful solution for scheduling applications.

Simulation provides a simple yet flexible method for generating a finite-capacity schedule for the factory floor. The basic approach with simulation-based scheduling is to run the factory model using the starting state of the factory and the set of planned orders to be produced. Decision rules are incorporated into the model to make machine selection and routing decisions. The simulation constructs a schedule by simulating the flow of work through the facility and by making "smart" decisions based on the scheduling rules specified.

In simulation-based scheduling, there are two types of decision rules that can be applied as each job step is scheduled: an operation selection rule and a resource selection rule. If a resource becomes available and there are several operations waiting to be processed by the resource, the operation selection rule is used to select the operation that is processed next. If an operation becomes available and it can be processed on more than one resource, the resource selection rule is used to decide which resource is used to process the operation. Together these rules determine the nature and quality of the final schedule. Because of the inherent complexity and variety present in manufacturing processes, there are a large number of rules that can be applied within a simulation model to generate workable schedules. Some of these rules are focused on objectives such as maximizing throughput, maintaining high utilization on a bottleneck, minimizing changeovers, or meeting specified due dates.

3.1 Why Simulation

Simulation competes against a number of different approaches for attacking the finite-capacity scheduling problem. It has a number of benefits that make it a compelling solution in these applications. These benefits include the following:

1. Extremely fast execution. A simulation model can typically generate a new schedule in a few seconds or minutes. This is critical in responding to unplanned events such as material shortages or machine breakdowns.
2. Flexible decision logic. Simulation can incorporate a wide range of decision rules to focus on any type of objective or represent any type of complex decision-making.
3. Simple implementation. Simulation-based finite-capacity scheduling is relatively simple to implement. This lowers the cost and reduces the implementation time.
4. High quality schedules. Compared to alternate methods that load an entire job at a time, simulation can generate very high quality schedules that often do a better job of maximizing resource utilization.

3.2 Special Considerations in Scheduling

Although in theory any general-purpose simulation language can be used as the basis for a finite capacity scheduler, there are a number of unique characteristics of this application domain that demand a number of special modeling features that may or may not be included in a simulation tool. These include the following:

1. Interactive Gantt chart display. The best way to view the resulting schedule is with a Gantt chart. It's also highly desirable to be able to directly edit the schedule from the Gantt chart.
2. Specialized reports. Schedulers expect special reports such as work-to list, tardiness reports, etc. The ability to easily generate and customize these reports is essential.
3. Integration with external data sources. The data for schedules typically comes from ERP or other business transaction systems. It is essential that this data can be automatically downloaded into the simulator. In many cases it is also necessary to integrate with real-time shop floor data collection systems.
4. Specialized scheduling rules. The quality of the generated schedule is largely determined by the scheduling rules that are specified for selecting resources and operations. A complete set of rules must be incorporated into the simulation tool to support a wide range of manufacturing applications. In some cases the ability to add custom rules is required.

3.3 Interpreting Results

In contrast to the simulation in the design stage, scheduling applications deal with deterministic data. All the features of a traditional modeling tool that help us interpret the results from random processes are of little value to us. We assume that we have complete information on the system, including routings, processing/setup times, material requirements, delivery schedules, etc. In a scheduling application, we assume away all of the randomness in the system.

As the real system runs, random events typically do occur. Machines break down, workers show up late or not at all, and material arrives late. These unplanned events will normally make our current schedule invalid and, in many cases, we will be required to regenerate the schedule using the new information.

At any point in time, our schedule gives us a picture of what will happen if no unplanned events occur. In reality, we will often end up with a schedule that is modified by unplanned events and will perform worse than the current schedule.

We can also use a traditional stochastic model of our scheduling application to assess the robustness and quality of our schedule. By adding random events to our model (e.g., breakdowns, shortages, etc.) and replicating the schedule generation process we can obtain measures on expected number of tardy jobs, average lateness, etc.

4 EXAMPLE APPLICATIONS

The final section of the tutorial presentation will cover a number of real-world applications of simulation in manufacturing. These include applications for both manufacturing design and scheduling, and also applications from the plant through supply chains.

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