SIMULATION OF DIFFERENT RULES IN DYNAMIC JOB SHOP SCHEDULING

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Abstract

A simulation-based scheduling for dynamic job shop is presented in this paper. Mean flow time performance for different scheduling approaches is compared through simulation experiments, under dynamic manufacturing environments that are subjects to disturbances such as machine breakdowns. A case study, 6 by 6 job shop scheduling problem was adapted with uncertainty elements added to the data sets. A simulation model was designed and implemented using ARENA to generate various job shop scheduling scenarios. These experimental results are used as reference indices for the real-time scheduling mechanism to select the better scheduling approaches for further evaluation based on the actual manufacturing conditions. The selected schedule is used until the deviation of actual performance from the estimated one exceeds a given limit, or when a major event occurs. A new simulation is then performed with the remaining operations to select a new schedule.

(Keywords: dynamic scheduling, job shop, simulation scheduling)

1. INTRODUCTION

Scheduling deals with the allocation of scarce resources to task over time. It is a decision-making process with the goal of optimizing one or more objectives [1]. Scheduling is important issue in management of organizations because it determines the cost and services reputation of the company with respect to the competition. The need to respond to market demand quickly and run plants efficiently raises complex scheduling problems in almost all but the simplest production environments.

2. JOB SHOP SCHEDULING

A job shop is a process-based manufacturing system in which jobs for different orders follows different routing or sequences through processes and machine [2]. The major characteristic of this system are flexibility, variety, highly skilled workers, much direct labor and great deal of manual material handling.

A schedule for job shop is an allocation of one or more time interval on one or more machine to each job. Job shop is one of the scheduling problems that have been study extensively because of its similarities to real production system. In a job shop, a job may require several different operations performed by different machines, and it may have to wait in several different queues. If jobs arrive at the shop randomly over time, the job shop is called a dynamic job shop [3].

The objective of job shop scheduling problem usually is to find a processing order or a scheduling rule on each machine for which a chosen measure of performance is optimized. Job shop scheduling problems are very difficult to solve. The analytical approach has been proved to be extremely difficult to solve, even with several limiting assumption [3].

Therefore, research on scheduling a job shop has focused primarily on identifying dispatching rules that perform well under a variety of shop condition or a variety of shop criteria [4]. In job shop scheduling, a dispatching rules is a priority assignment algorithm that is used to assign priority to the jobs in queue and then decide which task from a set awaiting processing is to be perform [4].

The great variation of dispatching rules reflects the amount of work in this area. Panwalker and Iskander [5] published a paper that categorized and listed 113 scheduling dispatching rules. In 1984, Sen and Gupta [6] reviewed the static scheduling problem whose performance measures are related in some ways to job due dates. In 1990, Ramashes [7] published survey paper on simulation-based research of job shop scheduling.

However, although a large number of dispatching rules have been studied, none of the claim to be the one that can operates effectively in all shop condition. In 1976, Weeks and Fryer [8] found that the performance of some dispatching rules was influenced by the due date assignment method. In 1983, Elvers and Taube [9] investigated the performance of five scheduling rules at six different shop-utilization levels and concluded that the relative performance of the rules was dependent on the shop-load level. In 1984, Baker [10] verified the existence of crossover points, with some rules performing better for thigh due dates and other for loose ones. Also, in 1984. Kiran and Smith [11] concluded that SPT is likely to perform better than slack per operation (S/OPN) in a shop that has high utilization and tight processing time independent due dates. There is no dispatching rule that has been shown to consistently produce better result than all other rules under a variety of shop-configuration and operating condition.

2.1 Dynamic Job shop Characteristics

The static job shop scheduling problem can be described as follows [12] Given M machines and J jobs, the J jobs are to be processed on the M machines. Each job consists of *P* operations processed on the *M* machines. A schedule is feasible if each job can only be processed on one machine and each machine can only process one job at a time. Some jobs have prescribed routing through the m machines, but the routing for each of these jobs may be different. The objective function is generally to minimize the maximum completion time (makespan), which is equivalent to minimizing cycle time.

Based on the definition of the Static Job Shop Scheduling problem, the dynamic job shop scheduling problem may be characterized as follows: in a manufacturing system which comprises *M* machines (*work stations*) the jobs arrive continuously in time. Each job consists of a specified set of operations, which have to be performed in a specified sequence (routing) on the machines. Schedules for processing the jobs on each of the *M* machines have to be found which are best solutions with respect to given objective(s) function or performance measure(s) . Because of the constrained information horizon (the arrival times, routings and processing times of the jobs arriving in future are not known in advance) only for those jobs currently in the shop processing sequences on the various machines can be determined. The decision as to which job is to be loaded on a machine, when the machine becomes free, is normally made with the help of a dispatching (scheduling) rule.

2.2 Scheduling Rules

A scheduling rule is used to select a job to be processed from a set of jobs waiting for services (these rules can also be used to introduce workpieces into the system, to route the parts in the system and also to assign parts to facilities). Scheduling rules may be static or dynamic. Because of the large number of scheduling rules, it is not obvious which scheduling rule to select in a given environment. However, have shown that the selection of the scheduling rules can have a significant impact on system performance. Hence, in recent years, substantial research and study has been carried out in analyzing these scheduling.

3. PROBLEMS DEFINITION

A case study of 6 by 6 job shop scheduling problem from Fisher and Thompson [13] was adapted in this study since the same case study has been widely referred by other researchers. The case study is shown in Table 1. For the purpose of this research, uncertainty elements were added to the original data set. This job shop consists of six machines, labeled as A, B, C, D, E, and F. The tasks were to manufacture six different parts.

This job shop was modeled using ARENA simulation software. The simulation model was designed to simulate the six-machine with each machine adopting similar dispatching rule. The job to be processed by a machine is selected from its respective queue. The physical system configuration is shown in Figure 1.

Table 1, A case study of 6 x 6 job shop scheduling problem (Fisher and Thompson, 1963).

	Operation No					
Job No.	1	2	3	4	5	6
1	C,3	A,10	B,9	D,5	F,3	E,10
2	B,6	C,8	E,1	F,5	A,3	D,3
3	C,1	D,5	F,5	A,5	B,9	E,1
4	B,7	A,5	C,4	D,3	E,1	F,3
5	C,6	B,11	E,7	F,8	A,5	D,4
6	B,3	D,10	F,8	A,9	E,4	C,9

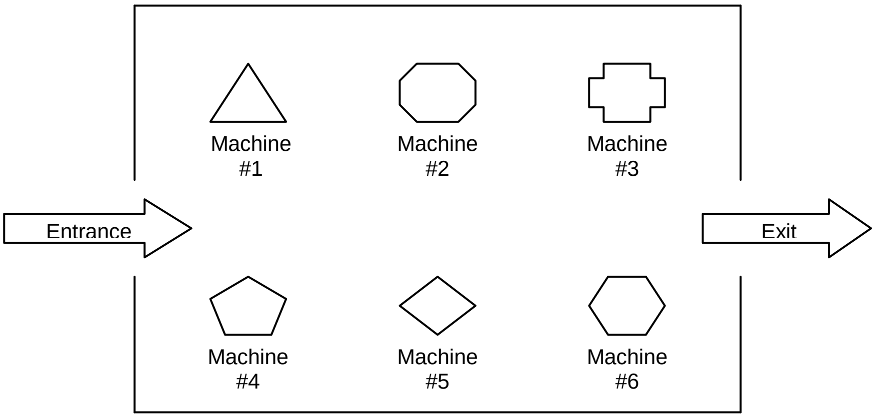

Figure 1: Physical configuration of a six-machine dynamic job shop.

Figure 4.1 shows each job comes directly through an entrance gate and passes to various machine according to its predetermined route. Each incoming job will posses a specific task characteristic assigned before entering the job shop. The task characteristics for each job are as the following:

- Routings details
- Job processing time on each machine where operation will be performed
- Scheduling rule

3.1 Simulation Model

As noted earlier, a computer simulation model to represent the job shop system was designed using ARENA. The performances of various job shop conditions when using scheduling rules, namely, first-in-first-out (FIFO), earliest-due-date (EDD), and shortest processing time (SPT) were evaluated.

The job shop used in this study consists of 6 unique work centers. The jobs were planned to arrive continuously with inter-arrival times generated from an empirical discrete distribution. The mean value chosen was chosen to create a certain expected shop utilization rate. Each job underwent 6 operations which were drawn from a normal distribution with means extracted from the original data (Fisher and Thompson, 1963). The schedule adopted a pure job shop routing whereby when a job left a work center, it was equally likely to go to each of the other work centers. Work center processing times were drawn from a normal distribution with means extracted from Fisher and Thompson [13]. Other assumptions adopted in the development of the model are:

- the resources were available continuously
- preemption of a job was not allowed
- set-up times were included in the processing times

- transportation times were excluded, and
- processing times of the jobs were known after their arrivals at the shop.

3.2 Steady-state Condition of the Shop (Warm up period)

In order to ascertain when the system has achieved a steady state, the shop parameters, such as the machine utilization level and mean flow-time of jobs need to be observed. It was found that the simulated system reached a steady state after the arrival of about 500 time units.

3.3 Run Length and Number of Replications

Job arrivals were generated using an exponential distribution. Three machine utilization levels, namely, “low”, “medium”, and “high” were studied. Thus, in all, for one type of process time distribution, one due date setting and three different utilization levels would resulted in a total of three experimental sets for every dispatching rule. Hence, for the three scheduling rules (FIFO, EDD and SPT), a total of nine simulation experiments were conducted. Each simulation experiment was replicated in twenty different runs. In each run, the job shop was continuously loaded with job orders that were numbered on arrival.

4. RESULT AND DISCUSSION

The problem of scheduling n jobs on a six-machine job shop, where machines are subject to random breakdowns, has been considered with respect to the Mean flow time performance measure. The earlier literature considered only the case when both machines have identical counting processes and the same breakdown distributions. This paper investigated the problem when these restrictive assumptions do not hold, in which case either machine 1 stochastically dominates machine 2, or machine 2 scholastically dominates machine i.

In the case machine 1 stochastically dominates, it has been shown that the FIFO rule performs well whereas the EDD rule performs well when machine 2 dominates. It has also been shown that when both uptimes and downtimes of the machines follow exponential distributions, then the SPT rule performs well. Furthermore, the results also has shown that Johnson rule performs fair, and in the cases it does not provide the best, its makespan is close to the best among the three different rules considered.

The results of the experimentation have been stated to be consistent with the available literature results. We conjecture that when the job shop is ordered, then the LPT rule is optimal (not only among the three rules stated, among all ules) when machine 1 stochastically dominates machine 2. We also conjecture that the SPT rule is the optimal rule for makespan when machine 2 stochastically dominates machine 1, again for ordered job shop.

5. CONCLUSIONS

We considered the case where machines are subject to random breakdowns with constant processing times. Another problem which might be considered is the one in which both machines are subject to random breakdowns and job processing times are modeled as random variables. For the case in which job processing times are exponentially distributed random variables, and the machine uptimes and downtimes follow exponential distributions (not necessarily with the same parameters), we conjecture that SPT rule will perform very well.

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