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A DYNAMIC APPROACH OF USING DISPATCHING RULES IN SCHEDULING

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Abstract

Manufacturing system in reality has dynamic nature due to certain unexpected events occur in changing environment, which requires rescheduling. This does not mean that every decision is made in real time. Based on the state of the working environment, determining best rule at right time is one of the alternatives. This study focuses on selecting the dispatching rule that show best performance dynamically both in static and changing environment. Simulation is carried out by employing genetic algorithm on flow-shop and job-shop scheduling problems to compare the performance of the dispatching rules dynamically. Out of many rules proposed in the past, it has been observed that under certain conditions, the SPT (shortest processing time) performs best in both the environment, when the total processing time of a job is not high relatively.

Keywords: Dispatching rule; genetic algorithm; predictive-reactive scheduling

1.0 INTRODUCTION

Scheduling plays an important role in most manufacturing and production systems. It involves resources and time, which must be addressed concurrently to satisfy constraints [1]. There are so many possibilities and uncertainties that are very hard to consider during static or predictive scheduling [2]. Extensive literature reviews on static deterministic scheduling can be found [3]. Most scheduling problems are NP-hard, and local disturbances can affect the global performance [4]. Dispatching rules [5, 6] are applied in scheduling to assign a job to a machine. This can be done each time a resource (machine) requires a new job. The job with the highest priority is chosen to be processed next [7, 8], whether the working environment has changed or not. Extensive studies on the application of dispatching rules for scheduling have been done. Geiger *et al.*, employed dispatching rule in single machine problem using Genetic Algorithm [9]. Dispatching Rules are used in complex manufacturing industry like semiconductor manufacturing [10]. Cost-based dispatching rules are discussed by Jayamohan *et al.* [11]. Developments in scheduling methodologies both in research and in practice as well as due to technological advances in computing have guided to the emergence of more effective scheduling methods [12, 13]. However, the ability to develop and test customized scheduling procedures in a given industrial environment continues to face significant challenges [14].

Shawn *et al.* [15] discuss about dynamic scheduling in cellular manufacturing systems. Heuristic techniques like Genetic algorithm is used to generate schedules by various researchers to evaluate the performance of robustness measures [16, 17]. Smith *et al.* [18] discuss about intelligent scheduling system in reactive scheduling. Sun *et al.* [19] has shown mechanism of changes in production order using dynamic scheduling approach

Ouelhadj *et al.* [20] has defined dynamic scheduling under four categories: on-line scheduling (purely reactive approach), predictive-reactive scheduling, vigorous predictive-reactive scheduling, and robust pro-active scheduling. In completely reactive scheduling, schedules are easily generated using dispatching rules. However, the solution quality is poor as decision is required in real time.

Predictive-reactive approaches search in a larger solution space, generate high quality schedules. Rajendran *et al.* [21], compares the dispatching rules of job-shop and flow shop problems and debated that no single rule has been found, which out performs all others; however, he has not considered the overall scheduling process in predictive-reactive environment. Cowling *et al.* [22] addressed an important gap between scheduling theory and practice. Hence, a procedure that could at least partially automate the development and evaluation of successful scheduling policies for a given environment would be extremely useful. By combining OR (operation research) and AI (artificial intelligence) techniques [23] can provide feasible schedule in dynamic environment. In dynamic scheduling approach, situation may come when one has to make certain decision in very short time otherwise, there will be loss of production. This study integrates dispatching rule with predictive-reactive methodology proposed by Rashid *et al.* [24] to find the performance of best rule out of some commonly proposed dispatching rules [7], which can be employed to make quick scheduling decision to increase production efficiency [25]. Next section explains about the scheduling methodology, then scheduling algorithm is outlined with problem formulation of 20 x 5 and 6 x6 flow-shop as well as 6x6 Job-shop problems [26]. Finally discussion and conclusion is presented.

2.0 PREDICTIVE–REACTIVE METHODOLOGY

The predictive-reactive scheduling methodology proposed by Rashid *et al.* [24], work on checking, repairing, posting, and improving (CRPI) loop. In the CRPI-loop, first step for "Checking" is to describe the manufacturing environment with the scheduling situation as detailed as necessary; like on-line information about the state of the workshop [27] in order to specify realistic situation for repairing. So the problem checking defines the parameter for "Repairing" phase; a solution for the scheduling problem is generated by using some specific heuristic technique like genetic algorithm [28, 29] with certain objective function, as makespan [30]. Schedules produced using dispatching rules were improved using genetic algorithms. Finally, the schedule generated in the past may be recorded on the message board, known as "Posting".

CRPI scheduling methodology = Predictive Scheduling + Checking +Repairing +Posting +Improving

CRPI, Predictive-reactive methodology is divided into two major parts WCE (without changing environment) i.e. employ predictive scheduling and CE (Changing environment) that requires analysis and repairing of schedule.

2.1 Problem Formulation

Flow-shop scheduling relate with problems in which the control of flow require sequencing for every job and for processing it on available set of machines [3, 31]. Job-shop scheduling problem relates to schedule production-times for N jobs on M machines with each job has its specific route. This problem is extremely complex and categorized as NP-complete [32, 33]

A 20x5 flow-shop scheduling problem (Pb-1), 6x6 flow-shop problem (Pb-2) and 6x6 Job-shop problem (Pb-3) are shown in Table 1, 3 and 5 respectively [26]. In case of CE higher job-priority is taken. These scheduling problems with higher job-priority are shown in Table 2, 4, and 6.These problems are chosen as models, in order to find the best solution in both WCE and CE environment. The algorithm proposed to solve scheduling problems based on CRPI predictive-reactive scheduling is as follows:

Suppose that m-machines M_j $(j = 1,2, \dots, m)$

have to process n-jobs J_i (i =1,2,3,………,n)

Step-1: Create predictive schedule (using GA) for set(s) of n-jobs J_i and m-machines M_j, in order to get the near optimal solution, with certain objective function, say maximum makespan (C_{max}) by using different repair strategies (R_p), where *R* means the number of different dispatching rules, like SPT, LPT, EDD; and (p =1,2, ---- , n)

Step-2: After certain time *t*, check the working environment information

Step-3: If, WCE signal reported; try to improve further predictive schedule (if needed) to obtain certain satisfying criteria

Else if, CE signal is reported; check and analyze the basic constraint violation; e.g. higher job-priority to be processed

Step-4: Check if CE signal "not-suitable time (t_n)" for analyzing, or "suitable time (t_s)" available for analyzing

Step-5: If CE, and time (t_s) is reported, apply various repair strategies(R_p), where (p=1,2, --- , n), and select the best priority rule based on (certain) objective function based on the suitable time (t_s) (it is assume here that time (t_s) is available all the time); depending on the problem formulation and criteria used to repair the schedule; a search engine (GA) is used; where $t > t_s$

Else if CE and time (t_n) is reported, find the best rule of similar situation from the message board

Step-6: After time t repeat step-2

If, WCE is reported

Table 1(Pb-1) 20x5 Flow-shop scheduling Muth & Th. [26]

No.	Tasks	Pri	20*5 flow-shop problem				
1	T01	0	1(29)	2(78)	3(9)	4(36)	5(49)
2	T02	0	1(43)	2(90)	3(75)	4(11)	5(69)
3	T03	0	1(91)	2(85)	3(39)	4(74)	5(90)
4	T04	0	1(81)	2(95)	3(71)	4(99)	5(9)
5	T05	0	1(14)	2(6)	3(22)	4(61)	5(26)
6	T06	0	1(84)	2(2)	3(52)	4(95)	5(48)
7	T07	0	1(46)	2(37)	3(61)	4(13)	5(32)
8	T08	0	1(31)	2(86)	3(46)	4(74)	5(32)
9	T09	0	1(76)	2(69)	3(76)	4(51)	5(85)
10	T10	0	1(85)	2(13)	3(61)	4(7)	5(64)
11	T11	0	1(11)	2(62)	3(56)	4(44)	5(21)
12	T12	0	1(28)	2(46)	3(46)	4(72)	5(30)
13	T13	0	1(10)	2(12)	3(89)	4(45)	5(33)
14	T14	0	1(52)	2(85)	3(98)	4(22)	5(43)
15	T15	0	1(69)	2(21)	3(49)	4(72)	5(53)
16	T16	0	1(72)	2(47)	3(65)	4(6)	5(25)
17	T17	0	1(21)	2(32)	3(89)	4(30)	5(55)
18	T18	0	1(88)	2(19)	3(48)	4(36)	5(79)
19	T19	0	1(11)	2(40)	3(89)	4(26)	5(74)
20	T20	0	1(76)	2(47)	3(52)	4(90)	5(45)

Table 2 (Pb-1) Job Priority -20x5 Flow-shop scheduling

No	Tasks	Job Pri	20*5 flow-shop problem (Job-priority)				
1	T01	10	1(29)	2(78)	3(9)	4(36)	5(49)
2	T02	0	1(43)	2(90)	3(75)	4(11)	5(69)
3	T03	0	1(91)	2(85)	3(39)	4(74)	5(90)
4	T04	0	1(81)	2(95)	3(71)	4(99)	5(9)
5	T05	20	1(14)	2(6)	3(22)	4(61)	5(26)
6	T06	0	1(84)	2(2)	3(52)	4(95)	5(48)
7	T07	30	1(46)	2(37)	3(61)	4(13)	5(32)
8	T08	0	1(31)	2(86)	3(46)	4(74)	5(32)
9	T09	0	1(76)	2(69)	3(76)	4(51)	5(85)
10	T10	0	1(85)	2(13)	3(61)	4(7)	5(64)
11	T11	40	1(11)	2(62)	3(56)	4(44)	5(21)
12	T12	0	1(28)	2(46)	3(46)	4(72)	5(30)
13	T13	50	1(10)	2(12)	3(89)	4(45)	5(33)
14	T14	0	1(52)	2(85)	3(98)	4(22)	5(43)
15	T15	0	1(69)	2(21)	3(49)	4(72)	5(53)
16	T16	0	1(72)	2(47)	3(65)	4(6)	5(25)
17	T17	0	1(21)	2(32)	3(89)	4(30)	5(55)
18	T18	0	1(88)	2(19)	3(48)	4(36)	5(79)
19	T19	0	1(11)	2(40)	3(89)	4(26)	5(74)
20	T20	0	1(76)	2(47)	3(52)	4(90)	5(45)

Table 3 (Pb-2) 6x6 Flow-shop scheduling Muth & Th. [26]

No	Tasks	Pri	6*6 flow-shop problem					
1	T01	0	3(1)	2(6)	5(6)	6(3)	1(3)	4(7)
2	T02	0	3(5)	2(8)	5(10)	6(10)	1(10)	4(4)
3	T03	0	3(5)	2(1)	5(7)	6(8)	1(9)	4(4)
4	T04	0	3(5)	2(5)	5(8)	6(9)	1(5)	4(3)
5	T05	0	3(9)	2(3)	5(5)	6(4)	1(3)	4(1)
6	T20	0	3(1)	2(3)	5(4)	6(9)	1(10)	4(3)

Table 4(Pb-2) Job-priority - 6x6 Flow-shop scheduling

No	Tasks	Job Pri	6*6 flow-shop problem (Job-priority)					
1	T01	10	3(1)	2(6)	5(6)	6(3)	1(3)	4(7)
2	T02	0	3(5)	2(8)	5(10)	6(10)	1(10)	4(4)
3	T03	0	3(5)	2(1)	5(7)	6(8)	1(9)	4(4)
4	T04	0	3(5)	2(5)	5(8)	6(9)	1(5)	4(3)
5	T05	20	3(9)	2(3)	5(5)	6(4)	1(3)	4(1)
6	T20	0	3(1)	2(3)	5(4)	6(9)	1(10)	4(3)

Table 5 (Pb-3) 6x6Job-shop scheduling Muth & Th. [26]

No.	Tasks	Pri	6*6 job-shop problem					
1	T01	0	3(1)	1(3)	2(6)	4(7)	6(3)	5(6)
2	T02	0	2(8)	3(5)	5(10)	6(10)	1(10)	4(4)
3	T03	0	3(5)	4(4)	6(8)	1(9)	2(1)	5(7)
4	T04	0	2(5)	1(5)	3(5)	4(3)	5(8)	6(9)
5	T05	0	3(9)	2(3)	5(5)	6(4)	1(3)	4(1)
6	T20	0	2(3)	4(3)	6(9)	1(10)	5(4)	3(1)

Table 6 (Pb-3) Job-Priority - 6x6Job-shop scheduling

No	Tasks	Job-Pri	6*6 job-shop problem (Job-priority)					
1	T01	10	3(1)	1(3)	2(6)	4(7)	6(3)	5(6)
2	T02	0	2(8)	3(5)	5(10)	6(10)	1(10)	4(4)
3	T03	0	3(5)	4(4)	6(8)	1(9)	2(1)	5(7)
4	T04	0	2(5)	1(5)	3(5)	4(3)	5(8)	6(9)
5	T05	20	3(9)	2(3)	5(5)	6(4)	1(3)	4(1)
6	T20	0	2(3)	4(3)	6(9)	1(10)	5(4)	3(1)

3.0 SIMULATION AND DISCUSSION

The CRPI-predictive-reactive methodology [34] is employed to solve the selected scheduling problems. Four priority rules are taken into consideration, SPT (shortest processing time), LPT (longest processing time), FSTLP (first shortest then longest processing time, and EDD (earliest due date) with makespan as objective function. Simulation is carried out to test the behavior of the priority rules.

Considering that the orders have been given by the customers. Predictive schedule is generated in WCE and the delivery dates are confirmed to the customer based on needs and priorities of the customer. Due to certain high- priority requirement, the customer has demanded to complete and ship urgently particular set of job (s) from the already ordered jobs. In this situation one has to reschedule the target problem with priorities in set of jobs already ordered by customer. This scenario is applied on the following scheduling problems.

Two flow-shop scheduling problems 20*5 and 6*6 and one 6*6 Job-shop problems have been tested. First, 20*5 flow-shop problem (Table-1&2) in WCE is simulated, the objective function is makespan. The efficiency of the three dispatching rules is compared in order to select the best rule for scheduling these jobs. Buffer-strategy is used. Sorting of buffer corresponding to SPT, give the best result at time interval of 1414 units.

The sorting of jobs with LPT takes maximum 1678 units, while computing of jobs with FSTLP provides 1564 units; as indicated in Figure 1. Later, the same problem is simulated in CE. The customer requires T03, T05, T07, T11, and T13 on priority bases. The simulation results obtained (Figure 2) in this case are: SPT-1498 units, LPT-1739 units, and FSTLP-1579 units. Due to changing environment, the criteria to evaluate the target problem has become multiple; first the system should consider the jobs with respect to earliest due date (EDD), and then evaluate the problem with respect to SPT, LPT, or FSTLP based on makespan of the schedule. In other words the behaviors of multiple rules are tested due to change in environment.

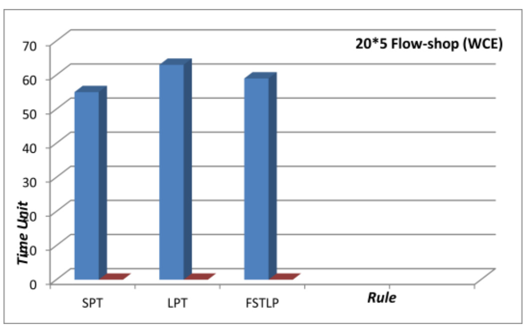

Figure 1 20*5 Flow-shop (WCE)

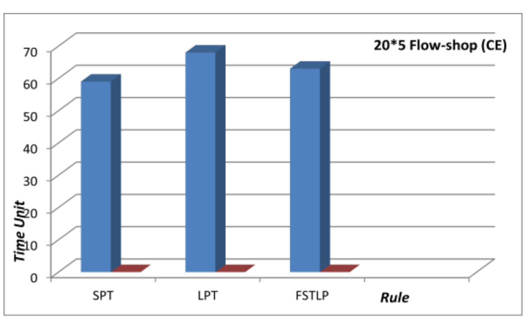

Figure 2 20*5 Flow-shop (CE)

Similarly, Pb-2, 6*6 flow-shop scheduling problem shown in Table 2 is tested in both WCE and CE. In WCE, 62 units obtained quickly for SPT, FSTLP, and for LPT-73 units (Figure 3); and in CE the same problem is simulated. The simulation results obtained in case of Job-priority of customer for T01 and T05 are: SPT-71 units, LPT-89 units, and FSTLP-78 units (Figure 4). Then 6x6 Job-shop problem the Pb-3 is tested. In this case the results of simulation in WCE are SPT-55 units, LPT-63 units, and FSTLP-59 units (Figure 5). In CE the customer requires T01 and T05 on priority bases. The simulation results obtained in CE are: SPT-59 units, LPT-68 units, and FSTLP-63 units (Figure 6). The result of the simulation has shown that SPT outperformed in both WCE and CE.

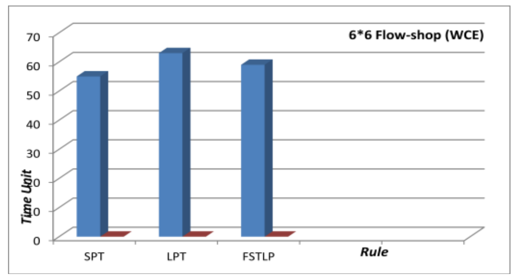

Figure 3 6*6 Flow-shop (WCE)

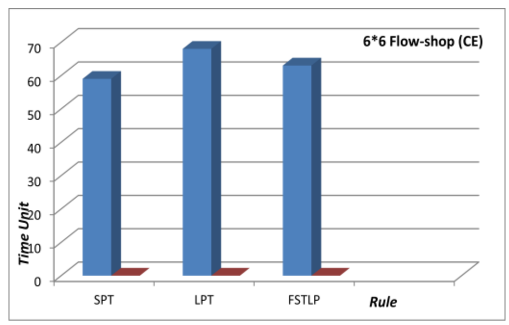

Figure 4 6*6 Flow-shop (CE)

Figure 5 6*6Job-shop (WCE)

Figure 6 6*6Job-shop (CE)

It is to be noted (phase-1) that the Job-priority assigned to Jobs in all three above problems are having low total job processing time relatively. In order to find out what will happen if all the selected jobs on higher-priority by customer are having higher total processing time relatively. So, in phase-2, the simulation is conducted again with changes in priority-jobs in CE for all three problems as follows: In case of Pb-1, the customer now requires T03, T04, T09, T14, and T20 on priority bases. The simulation results obtained in case of CE are: SPT-1621 units, LPT-1803 units, and FSTLP-1601 units (Figure 7). In Pb-2, the customer needs T02 and T03 on priority basis. The simulation results obtained in case of CE are: SPT-78 units, LPT-93 units, and FSTLP-79 units (Figure 8). While in Pb-3, the customer is looking to get T02 and T03 on higher priority. The simulation results obtained in this case are: SPT-69 units, LPT-78 units, and FSTLP-64 units (Figure 9). The simulation result in phase-2 shows that when the overall processing times of jobs are relatively higher, SPT not always show best performance.

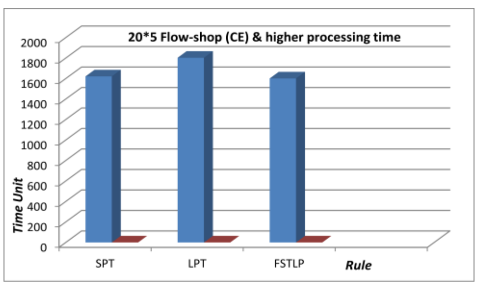

Figure 7 20*5 Flow-shop (CE) & higher processing time relatively

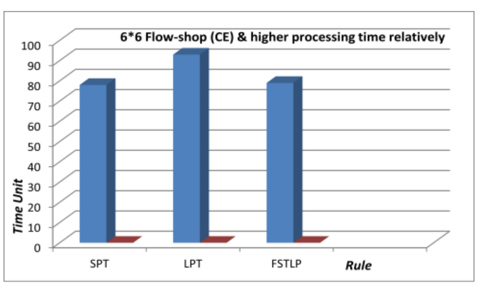

Figure 8 6*6 Flow-shop (CE) & higher processing time relatively

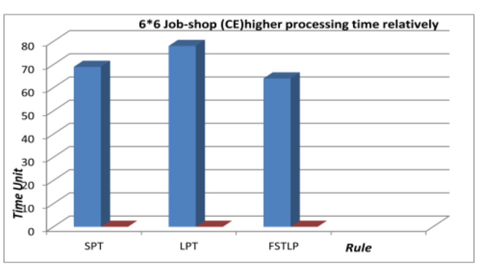

Figure 9 6*6 Job-shop (CE) & higher processing time relatively

4.0 CONCLUDING REMARKS

The performance of dispatching rule depends on scheduling process and conditions; however, based on the simulation results it has been observed that in case of higher job-priority (say, requested by customer) SPT performs better in both WCE and CE, out of the considered dispatching rules when the total job processing times are low relatively.

The results obtained in my simulation about SPT as one of the best dispatching rule is in-line with the researchers [35, 36, 37] studies. They also emphasis the importance of evaluating dispatching rule for particular working environment using dynamic scheduling approach, which can provide significant improvement in managing the scheduling activities.

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