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An Heuristic Approach for Solving 2-machine n-jobs Flow Shop Scheduling Problem with makespan objective

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Abstract: *Scheduling n - jobs on m - machines in the flow shop environment is NP-hard and also finds prominent place in the field of production scheduling. In flow shop environment, order of the machine is always fixed in which the jobs are processed in an order found by an algorithm. Johnson [1] developed the 2- machine n- jobs problem and provided an algorithm for the order A - B, where A and B denotes the machines. In this paper, we consider the problem of scheduling of n – jobs on 2- machines with makespan minimization objective for the order B - A. A new algorithm is developed and comparison is made with Jonson's algorithm. It was found that our algorithm is superior to Johnson's algorithm.*
Keywords: *Scheduling, Flow shop Scheduling, Heuristics, Makespan, Two machine problem.*

I. Introduction

Flow shop scheduling is a decision making procedure that is used on a regular basis in many manufacturing and services industries. Its aim is to optimize one or more objectives with the allocation of resources over given period of time. The resources may be machines in a workshop, crews at a construction site and runways at an airport and so on. The jobs may be operations in a production process, stages in a construction project, take – offs and landings in an air port and so on. Flow shop scheduling place an important role in most manufacturing and service systems as well as in most information processing environments. It is difficult to find an optimum solution in polynomial time. So it is important to improve the flow shop scheduling algorithms for reducing the running time of the machines which is useful in the area of production scheduling.

There are so many objectives to be minimized for a flow shop scheduling problems such as makespan, total job completion time, total flow time, mean flow time and tardiness and so on. In this paper, we considered the 2- machine n- jobs flow shop scheduling problem with makespan objective.

II. Literature Review

Over the last half century, most of the heuristics were developed for the objective of makespan minimization in flow shop scheduling problems. In 1954, Johnson [1] was the one who formulated first the flow shop scheduling problem and developed a heuristic algorithm for n-jobs 2-machine production scheduling problem with the objective of minimizing the throughput time (makespan) of all jobs. After him, so many researchers found different heuristic algorithms for makespan minimization in the flow shop scheduling for machine problems. In 1965, Palmer [2] developed a heuristic algorithm which can be applied to the large- sized problems by giving priority to the jobs so that jobs with processing times that tends to increase from machine to machine will get higher priority and known as Palmer's slope index method. Cambell, Dudek and Smith [3] extended Johnson's algorithm for the m – machine flow shop scheduling problem with makespan objective which is called CDS method. In that, Johnson's algorithm was applied in all the m-1 stages of the m-machine problem and an optimal sequence was chosen from the m-1 sequences obtained from m-1 stages.

Similar to the Palmer's slope index method, Gupta [4] provided another heuristic by defining the slope index in a different way by taking into account some attractive facts about the optimality of Johnson's algorithm. To provide a good solution as easily and quickly as possible, Dannenbring [5] suggested a procedure called rapid access (RA heuristic) in which the processing times of the two hypothetical machines are the sum of the products of the weights of a particular machine and the processing time of the corresponding machine of a particular job. Nawaz, Enscore and Ham [6] follow the priority rule in which a job with high total processing time on all machines should be given higher priority than job with low total processing time. Based on this, they developed a heuristic algorithm (NEH heuristic) which finds the optimal sequence in a constructive way so that adding a new job at each step and finding the best partial solution. In recent years, the above said algorithms are the basically used to compare with the new algorithms often by many researchers. Sayadia, ramezaniana and Nazab [7] presented a discrete firefly meta-heuristic with local search for makespan minimization in permutation flow shop scheduling problem. Uday Kumar Chakraborty and Dipak Laha [8] developed an improved heuristic for permutation flow shop scheduling problem and Dipak Laha and Uday Kumar

Chakraborty [9] proposed an efficient hybrid heuristic algorithm and a constructive heuristic by using the idea of job insertion technique for makespan minimization. Tejpal and Jayant [10] extended Palmer's heuristic for the flow shop scheduling which performs well better than CDS algorithm.

Sahu [11] made a comparative study of Gupta's, RA, CDS and Palmer's heuristics for 8 – jobs 3 – machines, 10 – jobs 8 – machines and 10 – jobs 10 – machines flow shop scheduling problems and concluded that RA heuristic performs well than other heuristics. Shu-Hui Yang Ji-Bo Wangb [12] developed a branch-and-bound algorithm for two machine flow shop scheduling to minimize the total weighted completion time problem. Several dominance properties and two lower bounds are derived to speed up the elimination process of branch- and – bound algorithm. Also they proposed a heuristic algorithm to solve the inefficiency of the branch – and - bound algorithm. Based on profile fitting approach, Quan-Ke Pan and Ling Wang [13] provided two simple constructive heuristics, namely weighted profile fitting (wPF) and PW. Also they developed three improved constructive heuristics, called PF-NEH, wPF-NEH and PW-NEH by combining the PF, wPF and PW with the NEH heuristics algorithm. Baskar and Antony Xavior [14] developed a new heuristic algorithm using Pascal's triangle to determine more than one sequence having optimal/near optimal makespan in flow shop scheduling problem. They compared their results with few popular heuristics. Jayakumar, Sathiya Shanthi and Meganathan [15] developed a heuristic algorithm for solving permutation flow shop scheduling problem.

While many algorithms deals with the single objective of makespan, a few researchers like Rajendran [16], Allahverdi and Al-Anzi [17], Ming- Cheng Lo, Jen- Shing Chen and Yong – Fo Chang [18] had worked on flow shop scheduling with multi-objective of minimizing more than one parameter like makespan, total flow time and mean completion time. Tang and Zhao [19] suggested an algorithm for scheduling a single continuous batching machine with the bi-criteria objective of makespan and total completion time. The concept of learning effect plays an important role in production engineering. Eren and Guner [20] developed a bi-criteria flow shop scheduling problem with a learning effect for the two machine problem where the objectives were makespan and weighted sum of completion time. Chia and Lee [21] developed the total completion time problem in a permutation flow shop with a learning effect. They evaluated the performance of so many well known heuristics when the learning effect is present.

III. Statement Of The Problem

In a flow shop problem, a set of n - jobs has to be processed on 2 - different machines in the same order. Each job $j, j = 1, 2, \dots, n$ must process on machines A and B with the non negative processing times $A_1, A_2, \dots, A_n$ and $B_1, B_2, \dots, B_n$. Each machine can processes at most one job and each job can be handled by at most one machine at any given time. The machines process the jobs in a first come first served manner. The jobs are processed on machine B first and then on machine A (i.e., in the order B – A). In Johnson's algorithm, while choosing a job with minimum processing time, a tie may occur on same machines and it can be broken by process the job with smallest index. In case of tie occur in between A_i, B_i, it can be broken by process the job which falls on machine A. In this work, we presented an algorithm by modifying Johnson's algorithm in which the tie is broken by giving priority to the job with smallest processing time on the other machine. The objective is to find a sequence that minimizes the maximum completion time (makespan).

Our Algorithm

In this section, we give our proposed algorithm to provide a solution for 2 – machine n – jobs flow shop scheduling makespan problem with makespan objective.

Step 1: Observe the processing times of the all the jobs and select a job with smallest one.
Step 2: If it is for the machine A, then schedule the job first.
Step 3: If it is for the machine B, then schedule the job last.
Step 4: In case of tie occurs on same machine, select the job with smallest index
Step 5: In case of tie occurs on different machines (A_i and B_i), select the job with smallest processing time on the other machines and process it first, if it belongs to machine A or last, if it belongs to machine B.
Step 6: Delete the corresponding job from the list.
Step 7: Repeat the above steps until all the jobs are scheduled.

The sequence obtained by this method is much optimal than the sequence obtained by Johnson's method.

Comparison with Johnson's Method

In this section an example is provided to illustrate our algorithm.

3.1. Example

Consider a FSP with 5 - jobs on 2 - machines.

Machines/ Jobs	1	2	3	4	5
M/C A	32	42	75	61	33
M/C B	28	33	53	82	90

For the above problem, the optimal sequence obtained by Johnson's method is 5 – 4 – 3 – 2 – 1 which gives the makespan value 382 units. By our method the optimal sequence is obtained as 2 – 5 – 4 – 3 – 1 with makespan value 373 units which is better than Johnson's method.

IV. Efficiency Of Our Algorithm

To test the efficiency of our heuristic algorithm, we generated 70 problem instances, each of 10 instances for 2 – machine with 4 – jobs, 5 – jobs, 6 – jobs, 7 – jobs, 8 – jobs, 9 – jobs and 10 – jobs. The processing times are chosen randomly from the numbers 1 to 99. The results are presented in Table 1. From the table, it is observed that our proposed algorithm gives better makespan value than Johnson's method.

Table 1

S L. NO.	PROBLEM SIZE	MAKESPAN VALUE		SL. NO.	PROBLEM SIZE	MAKESPAN VALUE	
		JOHNSON'S MEHTOD	OUR METHOD			JOHNSON'S MEHTOD	OUR METHOD
1	2X4 – 1	49	44	36	2X7 – 6	386	375
2	2X4 – 2	166	164	37	2X7 – 7	505	452
3	2X4 – 3	178	174	38	2X7 – 8	417	417
4	2X4 – 4	75	71	39	2X7 – 9	409	380
5	2X4 – 5	179	164	40	2X7 – 10	469	343
6	2X4 – 6	247	217	41	2X8 – 1	299	263
7	2X4 – 7	166	164	42	2X8 – 2	407	325
8	2X4 – 8	225	204	43	2X8 – 3	290	241
9	2X4 – 9	281	270	44	2X8 – 4	234	233
10	2X4 – 10	164	155	45	2X8 – 5	324	301
11	2X5 – 1	35	34	46	2X8 – 6	98	96
12	2X4 – 2	142	141	47	2X8 – 7	235	228
13	2X5 – 3	200	168	48	2X8 – 8	245	230
14	2X5 – 4	378	356	49	2X8 – 9	518	503
15	2X5 – 5	169	171	50	2X8 – 10	345	339
16	2X5– 6	464	445	51	2X9 – 1	216	190
17	2X5 – 7	382	373	52	2X9 – 2	314	311
18	2X5 – 8	273	263	53	2X9 – 3	314	295
19	2X5 – 9	99	98	54	2X9 – 4	184	173
20	2X5 – 10	246	238	55	2X9 – 5	248	233
21	2X6 – 1	177	140	56	2X9 – 6	258	246
22	2X6 – 2	394	373	57	2X9 – 7	357	346
23	2X6 – 3	65	63	58	2X9 – 8	233	224
24	2X6 – 4	94	88	59	2X9 – 9	482	476
25	2X6 – 5	211	187	60	2X9 – 10	326	325
26	2X6 – 6	73	70	61	2X10 – 1	497	496
27	2X6 – 7	87	80	62	2X10 – 2	257	251
28	2X6 – 8	212	194	63	2X10 – 3	337	324
29	2X6 – 9	137	131	64	2X10 – 4	353	334
30	2X6 – 10	364	343	65	2X10 – 5	436	430
31	2X7 – 1	434	378	66	2X10 – 6	438	432
32	2X7 – 2	424	377	67	2X10 – 7	598	588
33	2X7 – 3	493	482	68	2X10 – 8	710	675
34	2X7 – 4	162	147	69	2X10 – 9	496	489
35	2X7 – 5	291	282	70	2X10 – 10	520	502

V. Conclusion

In this paper, a new heuristics algorithm based on Johnson's algorithm is proposed for the 2 – machine n – jobs flow shop scheduling problem with makespan objective. From the analysis, the heuristics algorithm proposed by the authors is far superior than Johnson's method and hence we have more options of job sequences that can be implemented for greater production.

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