Solving Flow Shop Scheduling Problems by Using Hybrid Heuristics

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Abstract

The scheduling is an important of any manufacturing environment the success of scheduling greatly depends on the accuracy of the real time information. In this research, work is developed as static scheduling problem with random arrival of jobs; it has a potential offer to relief from some of the restrictions imposed by strict static scheduling approaches. The benefits of this type of scheduling include better tolerance and more flexibility. The main objective of this work is to develop a more generalized robust and flexible flow shop-scheduling algorithm that can be used in setup dependent flow shop scheduling problems. Further the proposed methodology can expedite a few selected jobs, which are behind schedule, without any unnecessary increase in make span. In this research work, an attempt made to solve the sequencing and scheduling of the flowshop with monocriteria of minimizing the makespan using the Meta heuristic tabu search. Two new Tabu searche based hybrid heuristic were proposed in the name of NETB, CDSTB were compared to the Tabu search.

Key words: Tabu search, NETB, CDSTB, Scheduling, Flow shop

1. Introduction

Scheduling problems arise when numbers of jobs are to be processed through number of machines. A flow shop is characterized by unidirectional flow of work with a variety of jobs being processed sequentially in a one-pass manner. A flow shop in which 'n' jobs to be processed through 'm' machines have been considered. Here initially it is assumed that a batch of jobs are ready for processing and while the processing is going on it is assumed that another set of jobs are arriving. This kind of flow shop scheduling is being considered and a new heuristic is constructed. The processing time of all the jobs are assumed to be known and all the jobs are processed in the same order in various machines. A particular set of jobs can be sequenced through all the machines and each sequence will have different performance measures such as makespan time, mean flow time, tardiness etc., It is difficult to suggest a sequence, which will optimize all the performances together rather these performances are purely independent among themselves. Although one can construct an example for which a schedule may be good at one measure, but perform poorly on others. In this paper makespan and total flow time is considered with equal importance while sequencing the flowshop problems in dynamic situation.

2. Literature Review

The flow shop-scheduling problem has been a keen area of research for over thirty years ever since Johnson [5] has proposed the two-stage scheduling problem with the makespan objective. The first significant work in the development of an efficient heuristic is Campbell, Dudeck and

Smith (CDS) [2]. Their algorithm consists essentially in splitting the given ‘m’machine problem into a series of an equivalent two-machine flowshop problems and solving it by Johnson’s [5] rule to find the sequence and then finding the sequence with best makespan. It has been observed that as the number of machines increases CDS fares better. Nawaz, Enscore and Ham [6] have presented a heuristic based on the premise that a job with higher total processing time should be given higher priority than a job with less total processing time.

The Flow Shops, new tasks arise over time in the process of manufacturing. The random arrival of jobs make planning, loading and scheduling functions more difficult. The attractiveness of flow shop scheduling problems to academicians and practitioners is mainly because of the wide range and depth in them, encountered in real-life. One of the main issues of flow shop scheduling is the development of effective time – based measures of performance such as minimization of mean flow time and make span time. In view of the nature and complexity of the flow shop-scheduling problem, simulation technique most widely used to analyze the scheduling problem and to evaluate the performance of dispatching rules. Until date, no attempt has been reported in minimization of mean flow time or make span time of flow shop problem to the best of my knowledge. The present work focuses on the development of a new heuristic approach for scheduling. This work is the first of its kind in developing an algorithm to address the problem of scheduling with the objective of minimizing the mean flow time and make span time considering both at the same time.

Objective of the current work is to develop a more general robust and flexible flow shop scheduling algorithm that can be used in setup dependent flow shop scheduling problems. Further the proposed methodology can expedite a few selected jobs, which are behind schedule, without any unnecessary increase in make span.

3.Terminologies and Algorithm

3.1 Terminologies Used

t_{ij} : Processing of i^{th} job on the j^{th} machine.

n : Total number of jobs.

m : number of machines in the flowshop.

ms : minimum makespan.

ms’ : makespan fed into tabu search.

ms’’ : makespan of the solution to tabu search from NEH.

ms’’’ : makespan of the solution to tabu search from CDS.

seq : job sequence.

seq’ : seed sequence fed to Tabu.

3.2 Technique of Hybridization with NEH, CDS

Let us consider the general flow shop problem of ‘n’ jobs (n = 1,2,3 …i), ‘m’ machines (m = 1,2,3 …j) with processing time t_{ij} represents the processing time of i^{th} job at j^{th} machine as shown in the table 3.1. The procedure adopted for hybridization is carried out as explained below. The Tabu search technique explained in the section 4 is applied with initial sequence as 1-2-3-….-n. The resultant sequence is found out and its makespan time is tabulated. The NETB , In case of hybrid NEH-Tabu Heuristic, the optimal sequence obtained from NEH heuristic is sent as an input to tabu search technique. The resultant sequence is found out and it is tabulated for a number of problems. The CDS- Tabu , Similarly in case of CDS-Tabu Heuristic, the initial solution obtained from CDS algorithm is given, as input to Tabu search technique and the resultant sequence is found out and tabulated.

3. 3 Algorithm for Tabu, NETB and CDSTB

Generate the general flowshop problem with 'n' jobs, 'm' machines with processing time for each job on each machine. The steps to be followed in executing all the above heuristic algorithms are detailed below.

3.3.1 Tabu

Step1: Initial seed sequence seq' is taken as 1, 2, 3, … n. find the makespan for

Corresponding sequence and let it be ms'.

Step2: Generate sequences from seq by swapping adjacent jobs, thus n-1 sequences

can be generated.

Step3: For all the generate sequences find makespan. Select the sequence with minimum makespan an assign the seq to seq' and the makespan ms to ms'. add the jobs swapped for corresponding sequence to active tabu list.

Step4: Find ((ms-ms')/ms)*100. if the value is less than 50 % then jobs in the active tabu list remains unchanged for further n/2 iterations. Otherwise it will remain unchanged for further (3*n)/4 iterations.

Step5: If the same sequence is repeated for 10*n iterations then go to step 6, otherwise go to step 2. Do the iterations for 100*n number of times.

Step6: Print the seq' and ms' which is the sequence that gives minimum makespan.

3.3.2 NETB

Step1: Solve the problem using NEH Heuristic. The resultant sequence and

makespan is assigned to variable seq and ms respectively.

Step 2. The sequence obtained by NEH Heuristic is given as input to the Tabu. Assign seq to seq' and makespan ms to ms'

Step3: Follow the steps given in Tabu from step2

Step4: Assign resultant sequence seq' to seq'' and makespan ms' to ms''.

3.3.3 CDSTB

Step1: Solve the problem using CDS Heuristic. The resultant sequence and

makespan is assigned to variable seq and ms respectively.

Step 2. The sequence obtained by CDS Heuristic is given as input to the Tabu. Assign seq to seq' and makespan ms to ms'

Step3: Follow the steps given in Tabu from step2

Step4: Assign resultant sequence seq' to seq''' and makespan ms' to ms''

Table 1 General flowshop problem of 'n'jobs and 'm' machines with their processing times

jobs	Machines						
	1	2	3	.	.	.	j
1	t_{11}	t_{12}	t_{13}	.	.	.	t_{1j}
2	t_{21}	t_{22}	t_{23}	.	.	.	t_{2j}
.	.	.	.	.	.	.	.
i	t_{i1}	t_{i2}	t_{i3}	.	.	.	t_{ij}

4.A Numerical Illustration of Tabu Search

The Tabu search technique is illustrated with 5 jobs and 5 machines problem for which the processing times of various jobs on machines are assumed as shown in the Table 2.

Table 2. Processing times for 5-jobs, 5-machines problem

Jobs	Machines				
	M_1	M_2	M_3	M_4	M_5
1	10	11	20	22	5
2	3	21	19	13	12
3	45	30	9	15	17
4	1	38	34	25	27
5	35	4	26	16	25

Let the initial sequence to be given as input for Tabu search technique be 1-2-3-4-5, the makespan time of which is **237**. Let it be ms'.

Table 3 Swapping neighborhood jobs

i	j	Sequence	Makespan
1	2	2-1-3-4-5	237
1	3	3-2-1-4-5	256
1	4	4-2-3-1-5	190
1	5	5-2-3-4-1	242
2	3	1-3-2-4-5	255
2	4	1-4-3-2-5	199
2	5	1-5-3-4-2	256
3	4	1-2-4-3-5	208
3	5	1-2-5-4-3	193
4	5	1-2-3-5-4	221

In Tabu search, the local neighborhood sequence is searched to improve the makespan time. With the given sequence, the various neighboring sequences generated by swapping the various jobs in the sequence. For example in the available sequence of 1-2-3-4-5 considering job (1,2) the swapping is done by interchanging the positions of these jobs. The resultant sequence after swapping will be 2-1-3-4-5. The corresponding makespan time is to be evaluated for all swapped sequences and it is shown in the Table 3.

The best swap is (1,4) and the sequence obtained by this swap 4-2-3-1-5 is shown in the Table 4, which yields the minimum makespan of 190. Let it be ms. Now (1,4) is kept as tabu active in tabu list. The number of iterations for which the particular swap is to be kept active is found out by the percentage difference between the old and new makespan. If ((ms-ms')/ms')*100 > 50% then keep the swap active for 3*n/4 iterations (or) if ((ms-ms')/ms')*100 < 50% then keep the swap active for n/2 iterations.

In this illustration, ((ms-ms')/ms')*100 = ((237-190)/237)*100 = 19.83%

Table 4 Comparison of NETB, CDSTB and Tabu

SL.No.	No. of jobs	No. of machines	% Number of times best makespan is yielded		
			NETB	CDSTB	Tabu
*1	5	5	70	60	60
*2		10	70	80	80
*3		15	30	50	90
*4		20	40	80	50
*5		25	30	70	60
*6		30	60	80	50
7	10	5	60	30	10
*8		10	30	60	30
*9		15	50	40	30
10		20	60	10	30
*11		25	80	0	30
12		30	60	20	20
*13	15	5	20	60	40
14		10	20	60	20
*15		15	60	30	20
16		20	60	10	30
17		25	60	20	20
18		30	40	40	20
*19	20	5	50	50	20
20		10	60	20	20
*21		15	40	50	20
22		20	50	20	30
23		25	60	40	- #

24		30	30	50	20
*25	25	5	30	40	50
26		10	80	20	-#
27		15	50	30	20
28		20	70	20	10
29		25	30	60	10
*30		30	30	50	30
*31	30	5	80	70	20
*32		10	80	20	10
33		15	10	80	10
34		20	40	50	10
35		25	50	40	10
*36		30	30	50	30

***** In this set two or more heuristic yields minimum makespan.

In this set Tabu has not given minimum makespan for any one of the problem.

Which is less than 50% and hence the swap is kept active for (5/2) or approximately two iterations. Now with the present sequence is taken as input, the Tabu search is carried out. The jobs swapped in the sequence of this iteration are remaining unchanged for further two iterations. The problem is iterated until the termination criterion mentioned in step5 of Tabu algorithm reached. The optimal sequence obtained for the above problem using this procedure is 4-2-3-5-1 with the minimum makespan of 184.

Fig. 1Comparison of CDSTB, NETB and Tabu

The same problem is executed in NETB and CDSTB as per the steps mentioned in section 3.2.2 and 3.2.3 respectively.

Table 5 Number of times minimum makespan obtained from NETB, CDSTB, Tabu.

SL. No.	Jobs	No. of Times Minimum Makespan obtained		
		NETB	CDSTB	Tabu
1	5	30	42	39
2	10	34	16	15
3	15	26	22	15
4	20	29	23	11
5	25	29	22	12
6	30	29	31	09
Total		177	156	101

5. Result Analysis and Discussion

The above three Heuristics are coded in "C" language. Three hundred and sixty problems have been tested of various sizes. In 5 jobs 5 machines category ten problems have been executed in three heuristics and the results are tabulated as their percentage number of times each heuristic yields best result. By varying the number of machines in steps of 5 upto 30 totally 60 problems have been executed. Similar set of problems with varying the number of jobs from 5 to 30 in steps of 5 totally 360 problems have been tested and tabulated in Table 5 For example in 5 jobs, 5 machines category ten problems have been tested and the three heuristics namely NEHTB, CDSTB and Tabu issued better results for 70%, 60% and 60% of the times respectively.

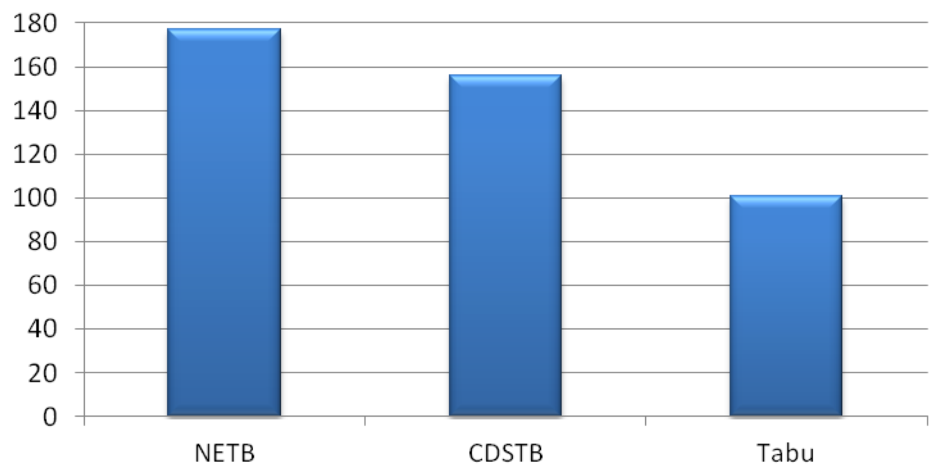

Fig.2. The overall performance comparision of the heuristics

The number of times the minimum makespan obtained from all the heuristics are tabulated in Table5.2. It is to be noted that the NETB performs better at 177 times, where as CDSTB is better for 156 times and the tabu is better for 101 times in all sets taken together. The same result is also shown in the fig 2 as a bar chart.

6. Conclusion

In this paper the problem of sequencing in flowshop scheduling with monocriteria of minimizing the makespan using the Meta heuristic tabu search have been addressed. Two hybrid tabus Searches, NETB Heuristic and CDSTB Heuristic, and the Tabu have been considered. In hybridization NETB is better when compared to other two hybridizations. Hence when NEH Heuristic's sequence is fed as input to Tabu Heuristic the optimal sequence with minimum makespan is obtained when compared to CDSTB and Tabu heuristics. The limitations to the study may be the sequence given for the Tabu is fixed and it may affect the neighborhood search for that sequence. In addition, along with the processing times, the due dates also may be considered and the tardiness of the job may be reduced. This paper is based on mono criterion of minimizing makespan as this can be extended to flow shop scheduling with multi objectives such as minimization of makespan.

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