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Solving flow shop scheduling problems with the objective of minimizing TCT when tie occurs

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Abstract

Scheduling process arises naturally upon availability of resources through a systematic approach in which prior planning and decisions should be made. Two machine flow shop scheduling problem (FSSP) was solved by Johnson in the mid of 1954 with makespan minimization as objective. Earlier we proposed two algorithms for the makespan objective; in this paper we intend to investigate the same algorithms for the objective of Total Completion Time of all the jobs (TCT). Experimental results had shown that one of our algorithm gives better results than the other two when the machine order is reversed.

Key words: Flow shop scheduling problem, Two machines, Total completion time.

1 Introduction

Scheduling is a decision making process as it decides the order in which the tasks are to be processed through the resources. It plays a major role in the production planning and control which reflects on economic activities of many manufacturing industries and service sectors. So one can apply FSSP as a decision making procedure on a regular basis. The main focusing of scheduling is that it optimizes the objectives with the available resources in a given stipulated time bound. The resources may be machines, persons, runway tracks at an airport etc. The jobs may be operations or stages in a production process, arrival and departure in runways etc. FSSP occurs when all the jobs have been processed in the same order on all the available machines. It has a vital role in all the service sectors and manufacturing industries for which finding an optimum solution in a polynomial is always critical when the number of machines is increased. It is necessary to keep in mind that the technological constraints should be maintained for each and every job to obtain better results for

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optimizing one objective or multiple objectives. Minimization of makespan is more important objective for a scheduler while many works has been done on minimization of the total completion time of all the jobs also.

2 Literature review

The concept of FSSP was first introduced by S M Johnson [11] in the mid of 1954 which has became standard in the field of scheduling theory. After him, so many researchers were developed the theory and found several heuristics for solving FSSP with different objectives. Palmer's Slope index method, Cambell et al. CDS method, Gupta's slope index method, Dannenbring's Rapid Access heuristic algorithm and NEH heuristic algorithm were the most important heuristic algorithms developed based on Johnson's algorithm which were found in [2, 4, 5, 13, 15] and they were be used as benchmark algorithms for comparison purpose. In [6], we proposed a new algorithm for the 2 machine n jobs FSSP by proposing Algorithm A and compared our results with Johnson's algorithm when the machine order is reversed. In [7, 14], we have encountered open shop scheduling problem for the TCT objective in general and hypothetical situations and in [8], we proposed an algorithm for solving permutation FSSP to minimize the makespan which provides better results than CDS method. S Jayakumar and G Vasudevan solved the permutation FSSP for make span objective in [9, 19, 20, 21]. S Jayasankari et. al. [10] proposed an efficient algorithm for FSSP with makespan objective which ensures better results than some of the algorithms available in the literature.

While many authors considered FSSP with the single objective of makespan, a few researchers like Allahverdi and Al-Anzi [1], M C Lo et al. [12] and C Rajendran [16] deals the FSSP with more than one objective like makespan, total flow time and mean completion time. L Tang and Y Zhao [18] suggested an algorithm for scheduling a single continuous batching machine with the bi-criteria objective of makespan and total completion time. S H Yang and J B Wang [22] developed a branch-and-bound algorithm for two machine FSSP to minimize the total weighted completion time. Many 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. In [17] we had proposed another algorithm namely Algorithm B for solving two machine FSSP with the objective of makespan minimization when tie occurs and the machine order is reversed which provides better results than Johnson's algorithm and algorithm A. Now in this paper we shall have interested on testing our algorithms developed in [6, 17] for the TCT objective also.

3 Statement of the problem

In a FSSP, a set of n-jobs has to be processed on 2-different machines in the same order. Each job $j, j = 1, 2, \cdots, n$ must process on machines A and B with the non negative processing times $A_1, A_2, \cdots, A_n$ and $B_1, B_2, \cdots, B_n$. Each machine can processes at most one job and each job can be handled at most one machine at any time. Once the job started its processing, it should be completed without any interruption. The machines process the jobs in a first come first served manner. The jobs are processed on machine B first followed by machine A (i.e., in the order B – A). Johnson algorithm breaks the tie situation occur on same machines 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_i while in CDS method, the tie situation was broken by giving priority to the job in the same position of the previous stage. For handling this tie criterion, we presented two priority rules as follows:

Priority 1: 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.

Priority 2: Select the job with largest processing time on the other machines and process it first, if it belongs to machine A or last, if it belongs to machine B.

There are many objectives to be optimized for FSSP such as makespan, total completion time of all the jobs, total flow time, mean flow time and tardiness and so on. In this paper, we considered the TCT objective for 2- machine n- jobs FSSP when tie occurs. The objective is to find a sequence that minimizing the TCT value when the machine order is reversed.

4 Proposed algorithms

In this section, we proposed two algorithms for solving 2-machine n-jobs FSSP by invoking the above said two priority rules.

4.1. Algorithm A [6]

Step 1: Observe the processing times of the all the jobs and select a job with smallest one.
Step 2: If it is from machine A, then schedule the job first in the sequence. If it is from machine B, then schedule the job last in the sequence.
Step 3: In case of tie occurs on same machine, select the job with smallest index. In case of tie occurs on different machines A_i and B_i, apply priority rule 1.
Step 4: Delete the corresponding job from the list and repeat the above steps until all the jobs are scheduled.

4.2. Algorithm B [17]

Step 1: Observe the processing times of the all the jobs and select a job with smallest one.
Step 2: If it is from machine A, then schedule the job first in the sequence. If it is from machine B, then schedule the job last in the sequence.
Step 3: In case of tie occurs on same machine, select the job with smallest index. In case of tie occurs on different machines A_i and B_i, apply priority rule 2.
Step 4: Delete the corresponding job from the list and repeat the above steps until all the jobs are scheduled.

5 Illustration

Consider a FSSP with six jobs on two machines as given in table 1. If we apply Johnson's algorithm for this problem, we got the sequence as $2-1-5-6-3-4$ which gives the TCT value 825. We got the sequence as $4-2-3-5-6-1$ if we apply Algorithm A which gives the TCT value 754 where as by applying Algorithm B, we got the sequence as $3-1-5-6-4-2$ which gives the TCT value 660.

Table 1: FSSP with six jobs on two machines

Jobs	1	2	3	4	5	6
Machine A	19	17	32	31	28	21
Maachine B	21	51	19	17	27	20

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6 Computational results

To test the efficiency of our proposed heuristic algorithms, 70 problem instances were taken into consideration, 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 arbitrarily from the numbers 1 to 99. Sum of the TCT values of 10 instances for each problem size is presented in Table 2. From that, it is observed that our proposed Algorithm B provides better results than Johnson's algorithm as well as algorithm A for the TCT objective. It is further observed that for the TCT objective concern, Algorithm B outperforms well than Johnson's algorithm in 60 out of 70 problem instances were tested. Out of 70 problem instances were tested, algorithm B provides best result than algorithm A in 55 problem instances, equal values in 2 problem instances and worst result in 13 problem instances.

Table 2: Sum of the TCT values obtained

Size of the Problem	Johnson's Algorithm	Algorithm A	Algorithm B
2X4	4441	4441	3917
2X5	7634	7592	7007
2X6	7053	6339	6130
2X7	16181	16116	13800
2X8	14008	13583	11735
2X9	15405	15239	14469
2X10	26573	26108	24717
Total	91295	89418	81775

7. Conclusion

In this paper, two heuristic algorithms proposed by the authors based on Johnson's algorithm were tested for the TCT objective on 2 – machine n – jobs FSSP. From the analysis, the heuristic Algorithm B is far superior to Johnson's algorithm as well as heuristic Algorithm A and hence we conclude that an algorithm which optimizes multi objectives is more essential in the field of production in the case of reverse order of machines. So one can utilize our proposed algorithm B for the implementation of effective production in a specially structured production environment.

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