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An Efficient Genetic Algorithm for Two-stage Hybrid Flow Shop Scheduling with Preemption and Sequence Dependent Setup Time

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Abstract

In This paper a two stages Hybrid Flow Shop (HFS) problem with sequence dependent set up times is considered in which the preemption is also allowed. The objective is to minimize the weighted sum of completion time and maximum tardiness. Since this problem is categorized as an NP-hard one, meta-heuristic algorithms can be utilized to obtain high quality solutions in a reasonable amount of time. In this paper a Genetic algorithm (GA) approach is used and for parameter tuning the Response Surface Method (RSM) is applied to increase the performance of the algorithm. Computational results show the high performance of the proposed algorithm to solve the generated problems.

Keywords: Hybrid Flow Shop scheduling, Sequence dependent set up times, preemption.

1. Introduction

The flow shop scheduling problem is one of the major and significant types of scheduling problems that was introduced by Holland in 1975th. In this kind of problems, a number of machines are located in series and jobs will be operated in a fix order. In Hybrid Flow Shop (HFS) problem there are some stages. In each stage there is at least one machine and at least one stage must contain two or more parallel machines. Production flow of jobs is from stage1 to the last stage and it is possible for a job to skip any number of stages. Each job is consisted of several tasks with different length of time. Fig.1. the set up time represent the amount of time that is needed to prepare the machines for operations. In this problem Preemption is allowed and it means that a job can be split and a part of it (task) may be delayed and operated in another moment of time. The hybrid flow shop problem happens in real world areas like electronic, and textile industries. There are also some cases in servicing areas like civil engineering, architecture and systems of transportation and information technology [1].

In literature review, Tavakkoli-Moghaddam et al. presented a bi-objective mixed integer programming model for unrelated parallel machines scheduling which is sequence independent setup time and some precedence relations between constraints [2]. Iravani and Teo considered the processing of M jobs in a flow-shop with N stations in which there is only a single server. Their objective is to minimize setup time and holding cost [3]. Jungwattanakit et al .investigated a problem that its objective is to find a schedule that minimizes a convex sum of make span and the number of tardy jobs in a static flexible flow shop environment [4]. Engin et al. represented a genetic algorithm with several types of operators and a full factorial experimental design was determined with their GA program by using the best values of the control parameters and the operators [5]. Shokrollahpour et al. propose a novel imperialist competitive algorithm for bi criteria scheduling flow-shop problem. In their study at a first stage there are several machines and at a second stage there is only one assembly machine [6].

The remainder of the paper is organized as follows. Section 2 provides a formal description of the problem. Solution methodology and the proposed GA are discussed in Section 3. Experimental design for parameter tanning is described in section 4. Results from computational examples are given in Section 5. Finally, Section 6 presents the general conclusions.

2. Problem definition

The presented HFS problem in this paper is considered in two stages, containing identical machines that are located in parallel lines. The jobs may be divided into several tasks and each task may be operated by any machines and what matters is the consideration of the tasks sequence. In this problem, two kind of set up time is regarded. The first one is the initial set up time that happens for the tasks that come to the machines at the beginning of the operations. The second one is the machine preparations time for the next task after operating previous one. It is the time that is considered for processing two tasks in order on a machine, and so this is considered as a sequence dependent setup time. In this problem also preemption of the jobs is allowed. Each job is consisted of several tasks that may be operated in separated times. In fact each task of each job is self-reliant and needs its own time to be processed on any machine.

In this problem some assumptions are presumed that are listed in the following:

- Machines are continuously available every time (machines breakdown or machine failure is not considered)
- Operation of jobs is done flawless.
- Processing of a task must be completed at a time and cannot be split.
- There is no precedence constraint between jobs.
- Each task of a job must be operated only on one machine.
- Each machine can process only one task at a time.
- Setup times are separately defined and are not combined with processing time
- Parallel machines in each stage are identical.
- Due date of each job is predefined.
- It is presumed that there is unlimited buffer between every two consecutive stages.
- Transportation time is negligible and it is considered in processing time.
- Preemption of jobs is allowed.

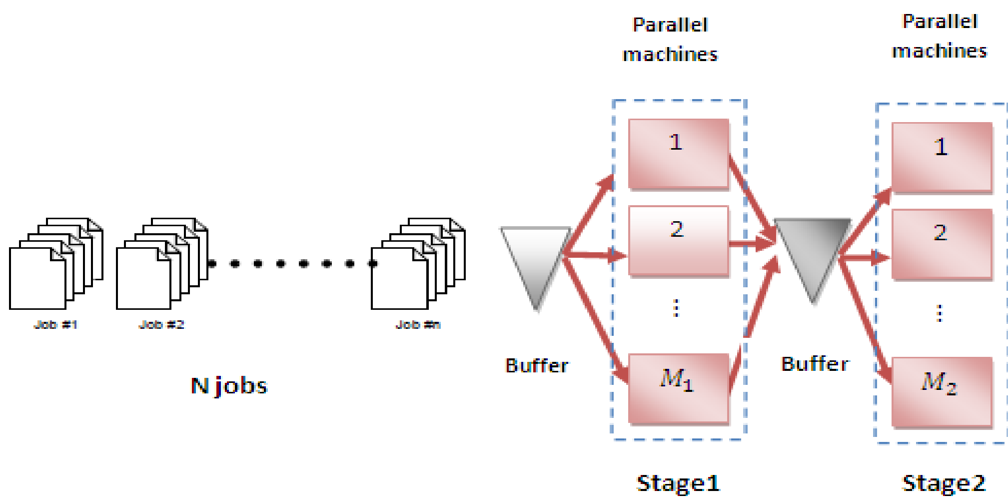

Figure 1. Structure of flexible flow shop system

3. Solution methodology: GA

In this paper the genetic algorithm (GA) approach is used to solve the proposed problem. The basic concept of GA is introduced by Holland (1975), and ever since it has been used for solving many linear and non-linear optimization problems. The GA is a comprehensive approach for searching the solution space to find good solutions in a comparatively little amount of time. The GA is a population based approach and start with initial population consisted of several chromosomes and each chromosome is made up by a set of genes.

3.1. Chromosome representation

In this problem, the designed chromosomes are in two dimensions and the representing matrix has two rows to make it possible for jobs to be split. The machine numbers are put into the first row and the job numbers are inserted into the second row. An example of chromosome representation is illustrated in fig.2.

Figure 2. Chromosome representation

Machine	1	2	1	3	*	3	2	2	3
Job	1	2	2	1	*	2	2	1	1

In second row, the repeating numbers of a job reflect the scheduling order of its tasks process. This means that the assigned genes to a job, shows the total number tasks of a job and its order of process. The symbol (*) cuts the chromosome to different stages. For instance, at stage 1 the first task of job 1 and the second task of job 2 are done on machine 1. The first task of job 2 is processed on machine 2 and the second task of job 2 is processed on machine 3 respectively.

At stage 2, the first task of job 2 and second task of job1 are done on machine 3 and the processes of second task of job 2 and first task of job 1 are done on machine 2 respectively.

After generating of the initial population, objective function must be calculated. In this problem the objective is to minimize the weighted sum of completion time and maximum tardiness and that means the better solutions have smaller values. So the fitness values will be computed as following:

$$Fitness\ Value = \frac{1}{objective\ function}$$

Then, after computing fitness values, better solutions have more chance to be selected using the roulette wheel mechanism as a selection approach. It is clear because the selected chromosomes with better fitness values have more chance to produce better offspring. And also the reproduction operator keeps the best current solutions by simply making copies of them to the next generation to make guarantee that they will not be missed.

3.2. Crossover operator

In this research the Modified Position Based Crossover (PBX) is used and its procedure is explained in the following steps:

Step1: A set of random positions is selected from parent 1.

Step2: the genes located in the selected positions will be copied to the same positions into the offspring. Then the positions in parent 2 with the identical values with the selected genes from the parent 1 will be identified and omitted.

Step3: the unfilled positions of the offspring will be placed by the genes of the remainder positions from the parent2 in left to right order.

The mentioned steps are shown schematically in the fig.3.

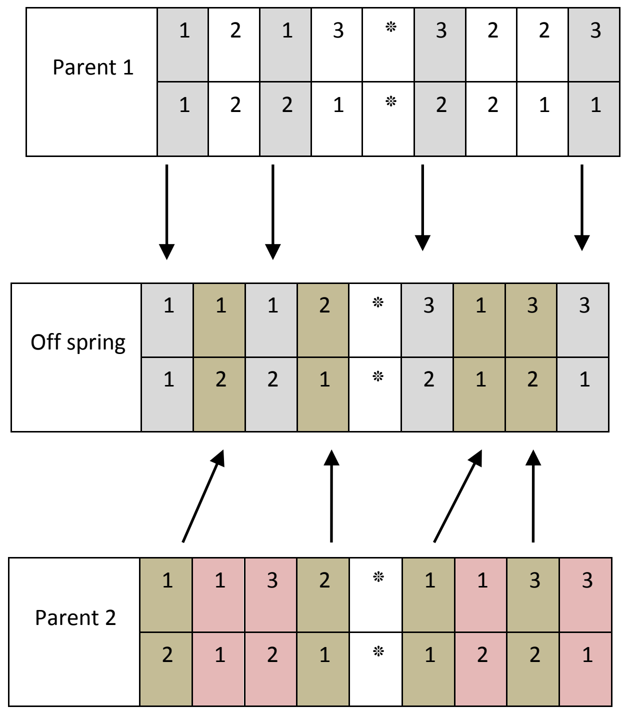

Figure 3. illustration of the crossover operator

3.3. Mutation operator

This operator take place after the crossover operator and in this paper the modified position based mutation (PBM) is utilized. This operator selects randomly two genes position with the same stage number and exchanges them with each other. This procedure is showed in fig.4.

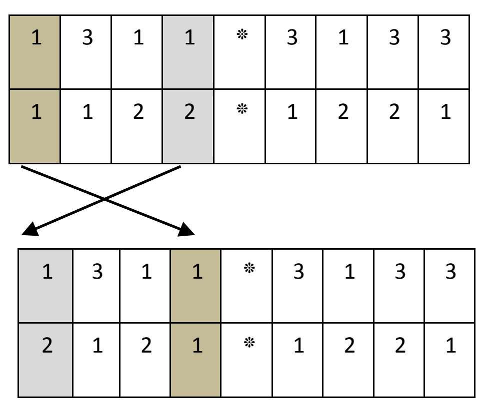

Figure 4. the illustration of the mutation operator

After applying the mentioned operators, then the fitness functions of the new generation must be recomputed and the evolution procedure will be continued to reach the maximum number of generations.

4. Experimental design

In design of experiments, the main parameters of the meta-heuristic approach that have significant effect on solutions quality are studied and their values will be determined. In this

Paper a Response Surface Method (RSM) is used. In this method, parameters must be selected and their range of variations must be specified by sensitivity analysis. Table 1:

Table 1. parameters and their ranges

Parameters	Level
Pop-Size	(20-50)
Cross over Ratio	(0.8-0.9)
Mutation Ratio	(0.03-0.05)
PBX Ratio	(0.2-0.4)
Iteration	(200-500)

Five factors are considered in table 1; each one can be measured in two levels; up (high level) and down (low level). And so the method uses 2^5 fractional experiments. Each factor is either in high level or low level and there are about 20 central and radial experiments, Totally 52 ones. After implementing these experiments and specifying their objective value, a quadratic model will be fitted. Then this quadratic model will be solved by using exact methods considering the ranges of parameters variation as constraints. The values of parameters will be set to the gained exact solutions of the model. [7], [8] .In table 2, the tuned values of the considered parameters are displayed.

Table 2. exact values of parameters

Parameters	Value
Pop-Size	48
Cross over Ratio	0.8
Mutation Ratio	0.03

PBX Ratio	0.2
Iteration	500

5. Computational results

After tuning of parameters, several problems are produced to verify the performance of the proposed GA. The problems are generated in uniform distribution according to the table 3.

Table 3. the range of problems characteristic

Due date	Process Time	First Setup Time	Middle Setup Time	Parts of Jobs
[20,100]	[5,20]	[1,5]	[1,6]	[1,4]

Computational results are shown in table 4. (m1, m2) is the number of machines at first and second stages and N shows number of jobs. OB is objective value and DV in the following formula shows deviance values of Lingo program and GA approach.

$$DV = \frac{OB_{GA} - OB_{Lingo}}{OB_{Lingo}} \times 100$$

Table 4. Results of expriments

N	(m1,m2)	Objective Value	Deviation	Time (Second)
3	(2,2)	60.4	0	62
	(2,4)	48.2	0	49
	(4,2)	45.6	0	68
	(4,4)	32.4	0	63

4	(2,2)	121.2	0	110
	(2,4)	104.8	0	85
	(4,2)	101.6	0	82
	(4,4)	62.6	0	117
5	(2,2)	121.6	0	63
	(2,4)	68	0.03	115
	(4,2)	121	0	124
	(4,4)	63.2	0	126
6	(2,2)	141.8	0.007	212
	(2,4)	84.4	0.014	137
	(4,2)	134.6	0	341
	(4,4)	70.2	0.014	295
7	(2,2)	169.2	0.024	190
	(2,4)	98.8	0.046	216
	(4,2)	160.2	0.165	229
	(4,4)	83.4	0.039	151
8	(2,2)	189.8	0.049	195
	(2,4)	128.2	0.064	352
	(4,2)	192.8	0.081	274
	(4,4)	94.8	0.041	103

6. Conclusion

In this paper a two-stage hybrid flow shop scheduling problem is considered and an efficient genetic algorithm is proposed to solve it. The parameters of the GA are tuned by the response surface method to increase the algorithm performance and also the quality of the solutions. Computational results show the high performance of the proposed algorithm to solve the generated problems in a reasonable of time.

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