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RECENT TRENDS: OPTIMIZATION TECHNIQUES USED IN IDENTICAL PARALLEL MACHINE SCHEDULING

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Abstract

This paper summarizes the different optimization techniques which are used in identical parallel machine scheduling problem. Parallel machine scheduling problem is more about allocating a set of jobs into different number of parallel machines in order to meet customer needs. Among the various performance measures few important objectives are considered. First important objective is minimizing the make span, secondly the total completion time and thirdly the maximum lateness. some of the intelligent optimization techniques are reported successfully in the literature to address optimization issues in scheduling of parallel machines, among all Tabu Search (TS), Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Simulated Annealing Algorithm (SAA), and Harmony Search Algorithm (HSA) are discussed briefly in this paper.

Keywords: Parallel Machine Scheduling, Optimization Techniques, Make Span, Lateness and Total Completion Time.

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1. INTRODUCTION

In the manufacturing industry, scheduling of machines plays a key role concerning with the allotment of machines for performing different operations in a way that the desired performance measures could be obtained such as flow time, earliness, makespan and tardiness[1, 2]. The parallel machine scheduling is one of the categories among the different categories of the single machine shop scheduling [3]. The parallel machines scheduling refers to manufacturing facility where every job processed in the similar type of machines. It is difficult to build a common procedure which give optimum solution to the production scheduling problem for minimization of make span in different stages of production shop when there are number of identical parallel machines at a bottleneck stage. The general procedure followed like applying Johnson's rule to obtain initial sequence, secondly move the current job with tiny processing time at initial stage to first position in the sequence, and thirdly using the resulting sequence to schedule the jobs in parallel machine production shop [4].

The utilization of resources in parallel is common in the manufacturing industry, for instance the automated guided vehicles usage in flexible manufacturing system for feeding to parallel machines by decomposing procedures in multistage systems [5, 6]. In generally the machine scheduling consists of a single machine to process n jobs. The objective of such kind of problem is to optimize the performance measure by scheduling n jobs on a single machine [7, 8].

The different performance measures of a single machine scheduling are minimizing the maximum lateness, minimizing the mean flow time, minimizing the total tardiness and maximizing the number of tardy jobs. In single machine scheduling the makespan is the important objective and which is mostly dependent on the sequence setup times. In generally this sequence setup time is equal to the sum of the processing times [9, 10]. Where as in parallel machine scheduling make span is the major considerable objective which is often deals with the balancing of the different load on the parallel machines. In such kind of scenarios, foremost one has to determine which job have to processed on which machine, later stage, one has to consider to determine the sequence of the jobs assigned to different machines. In both the stage the make span is the objective in allocation of the jobs and machines. Another important aspect is the considering the preemption, which plays important role in parallel machine scheduling than the single machine scheduling. Preemptions are key element when all jobs are released at the same time in parallel machine scheduling.

In a given set of manufacturing scenario n jobs (j), each job is associated with P_j (Processing time where $j = 1, 2, 3……n$), and a set of m parallel identical machines (i) and these parallel identical machines process at most on job at a time (i=$1, 2......m$). In the practical scenario, the identical parallel machine scheduling problem is for the assigning each job to each one machine, so that the objective is to be minimizing the maximum completion of each job, that is called make span. In generally we assume that in this kind of scenario, $1 < m < n$ and the processing times are integers. The identical parallel machine scheduling problem is denoted as $P \parallel C_{max}$ in the three field classification by Graham et al. [11] which is NP-hard in the strong sense. This is one of the popular combinatorial optimization problems in many real-world applications.

The problem $P \parallel C_{max}$ is as an integer linear programming model with usage of binary variable $x_{ij,}$ taking values one if and only if job *j* is assigned to machine *I* (*j=1,2, …, n; i=1,2, …..,m*):

Minimize z (where z= optimum make span) (1)

Subjected to $\sum_{j=1}^{n} P_j x_{ij} \leq z \quad (i = 1, 2, \dots\dots\dots, m)$ (2)

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad (j = 1, 2, \dots\dots\dots, n) \qquad (3)$$

$$x_{ij} \in \{0,1\} \quad (i = 1, 2, \dots\dots\dots..m;\ j = 1, 2, \dots\dots\dots, n) \qquad (4)$$

The other objective was studied to minimize the total tardiness which is given on the following equation

$$T = \sum_{i=1}^{m} \sum_{j=1}^{n_i} T_{s_j} \quad (i = 1, 2, \dots\dots\dots..m;\ j = 1, 2, \dots\dots\dots, n) \qquad (5)$$

Where S_j is the index of job and T_{s_j} is the tardiness of job S_j

The tardiness time of job S_j is calculated using the following equation

$$T_{s_j} = \max(0, the\ difference\ of\ completion\ time\ of\ job\ Sj\ and\ due\ date\ of\ job\ Sj \qquad (6)$$

In the literature ample number of technical mathematical programs are available as optimization algorithms some of these are Linear programming, Goal Programming, Dynamic programming and sequencing models etc. These programming techniques are not well versed for the complex and mixed variety scheduling problem which can give trust worthy solutions, and these are very much suitable for simple and small size scheduling problems. In general, the common techniques are BBA(Branch Bound Algorithms), DM(Decomposition Method), LRM (Lagrangean Relaxation Method), some of the local search algorithms such as SAA(Simulated Annealing Algorithms, TA(Threshold Annealing, VNSA (Variable Neighborhood Search Algorithm), TS(Tabu Search), and some of the evolutionary algorithms are GA(Genetic Algorithm, PSO (Particle Swarm Optimization, HSA (Harmony Search Algorithm) [12]. In the literature it reveals that some of the heuristic algorithms performs efficiently and effectively which are known to excellent algorithms, but they get struct with local search entrapments, which are needed in refinement of the exploration related to the global search and local search. For this exploration required large search space to get better near approximate solution which is needed refine and tune the vicinity of the search space. Due to these critical characteristics and different features involvement they popular in solving the complex scheduling problems. In this paper discussed some of the researchers works which are popularly used to produce satisfactory schedules for identical parallel processing scheduling

2. PROBLEM OF IDENTICAL PARALLEL MACHINE SCHEDULING

In general, the dynamic programming methods, mixed integer linear programming techniques are the common mathematical solvers for identical parallel machine scheduling problems. The common meta-heuristic techniques are applied for solving identical parallel processing machine scheduling problem such as TS (Tabu Search), SAA (Simulated Annealing Algorithm), GA (Genetic Algorithm), PSO (Particle Swarm Optimization), HSA (Harmony Search Algorithm). The frame work of Identical Parallel Processing Machine Scheduling is depicted in the Figure 1.

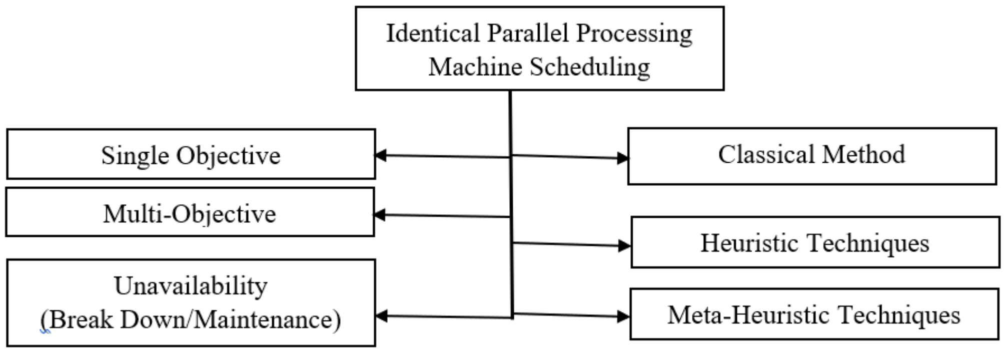

Figure 1 Framework for Identical Parallel Machine Scheduling

2.1. Dynamic programming and mixed integer linear programming

Rajaraman [13, 14] attempted to study the minimize the tardiness, to minimize the waiting cost and to minimize cost of the processing using dynamic programming. Rajaraman has been introduced allocating the one to one on one machine on *m* machines. It is followed unscheduled *n-m* jobs are allocated to the *m* machines one at a time. Dogramaci et al. [15] have studied on the weighted tardiness problem using a *zero-one integer programming.* Elmaghraby et al. [16], Barnes et al. [17] and Sarin et al. [18] have studied on the development of Brach Bound algorithms for the sequencing problems when all the jobs are available at a time and to minimize total tardiness [19, 20].

Adgekhodaee et al. [21] have formulated integer program to minimize tardiness for scheduling parallel identical machines. Shim et al. [22] have developed a branch and bound algorithm for identical parallel processing machines scheduling in flexible manufacturing system by taking real problem in the printed circuit board making industry, mainly they have considered for job splitting into different parallel machines. Tanaka et al [23]. also developed similar algorithm to minimize the total tardiness on identical parallel machine scheduling by applying the Lagrangan relaxation technique. Ranjbar et al. [24] have also developed two branch and bound algorithm focusing on customer satisfaction and provided optimal solution by minimizing the make span. Xu et al. [25] have considered to minimize the completion time and makespan by formulating the mixed integer programming.

2.2. Tabu Search

Tabu search (TS) is a metaheuristic technique which guides the local search to explore the solution space beyond its local optimality. Tabu search is a premise based which provides the optimal solution. In TS, one need to qualify the premise in intelligent way by incorporating adaptive memory and responsive exploration. Tabu search is more concerned on finding new and more effective ways to train the premise that can strengthen the intelligent search.

Valls et al. [26] have studied the parallel machine scheduling to minimize the setup times, release times and due dates by applying Tabu search technique. Armentano et al. [27] have considered their study on identical parallel machine scheduling for minimizing mean tardiness. Amaral et al. [27] reported the that Tabu search technique is the effective technique to find out minimum tardiness in job-shop scheduling problems. Kim and Shin [28] have made study on minimization of maximum lateness of the job on parallel machine by applying the restricted Tabu search algorithm. They have also considered the key inputs for the study are sequence depended setup times, release times and due dates. A Tabu search is one of the common techniques which is used to tackle the complex identical parallel machine scheduling for the objective minimizing the total tardiness [29, 30].

2.3. Simulated Annealing Algorithm (SAA)

Simulated Annealing Algorithm (SAA) was introduced by Kirkpatrick et al. [31]. Simulated annealing is a search procedure in which accepts the solution that worse than the existing one. This simulation begins at an initial solution, evaluates its solutions using an evaluation function and samples a new solution in the neighborhood space, if new solution improves, then it is accepting the existing solution.

Lee et al. [32] have applied simulated annealing algorithm to solve independent setup times of scheduling machines incurred in identical parallel machines scheduling their objective was to minimize processing time, and due date. Koulamas [33] proposed a hybrid and heuristic simulated annealing for identical parallel machine scheduling to minimize tardiness in the process; also applied decomposition principles which is very much effective and yielded solutions on any individual machine scheduling. Radhakrishnan et al. [34] and Melouk et al. [35] have studied on identical parallel processing machine scheduling, their objective was to minimize the make span and the due dates which were deviating from the completion time schedules. Wen-Chiung Lee et al. [36] have made an attempt to study on identical parallel process machine scheduling to minimize the make span time using simulated annealing algorithm and they found that developed algorithm was effective and which gave near optimal solution. Damodaran et al. [37] have studied on the parallel processing machine scheduling in which there were each job had non-identical size, non-zero ready time and an arbitrary processing time, they have found the optimal solution using simulated annealing algorithm. Simulated annealing algorithms were also applied in fighter jet air refueling scheduling problems [38] to address due date to avoid low fuel level in the tanks, here the objective was to minimize the total weighted tardiness [39].

2.4. Genetic Algorithm (GA)

Genetic Algorithm (GA) is based on the mechanism of natural genetics and natural selection. GA was introduced by evolution of family computational models. The implementation of GA begins with a population of chromosomes. The algorithm evaluates these structures and assigns reproductive opportunities in such a way that the chromosomes represents nearer-best solution to the objective and also give opportunity to those chromosomes which are not performing as expected.

Cheng et al. [40] have studied on identical parallel processing machine scheduling to address the an earliness/tardiness scheduling problem and their objective was to minimize the maximum weighted lateness using genetic algorithm. Min et al. [41] have addressed for solving large scale identical parallel processing machine scheduling with ample number of jobs and machines and their object was to minimize the make span by using genetic algorithm. Yun [42] have made an attempt to study different categories of parallel machine scheduling problems like preemptive job-shop scheduling and non-preemptive job-shop scheduling, has introduced new genetic algorithm with fuzzy logic controller. Yun proposed in genetic algorithm new gene representation method, new crossover and constant programming. Rajakumar et al. [43] have studied the parallel machine scheduling using genetic algorithm with the objective of workflow balancing. Tseng et al. [44] have developed a new hybrid genetic algorithm technique for parallel machine scheduling in flow shop scheduling system to minimize the maximum make span. Chaudhary et al. [45] have studied on identical parallel machine scheduling for job and worker assignment on machines with the objective of to minimize the total tardiness using genetic algorithm technique. Moghaddam et al. [46] have studied on parallel machine scheduling to solve bi-objectives such as tardiness and total completion of all jobs. Balin [47] have proposed genetic algorithm with the combination of fuzzy processing to solve parallel machine scheduling problems with the objective to minimize maximum completion time. Imran et al. [48] have proposed spreadsheet-based genetic algorithm approach for solving identical parallel machine scheduling and worker assignment with the objective to minimize make span. Researchers also have made an attempt to on job shop scheduling problems and dynamic job shop scheduling problems with random job arrivals and machine non availability using genetic algorithms [49, 50].

2.5. Particle Swarm Optimization (PSO)Algorithm

Particle swarm optimization was introduced by Eberhant and Kennedy in 1995 which is based on the behavior of bird flocking or fish schooling. In this technique the particles are the potential solutions. The particle adjusts its position by its own experience and also by neighboring particle experience to get best known position by utilizing best known search space. This best-known position is remembered for next time search to reach best nearer optimal solution. In this case each particle is occupied by three dimensional vectors in search space. These three dimensions are velocity, displacement and position. These are updated frequently in search space to optimize best solution.

Liu et al. [51] have studied on flow shop scheduling problems with parallel machines for minimizing maximum completion time and they have proposed hybrid particle swarm optimization. Liao et al. [52] and Pan et al. [53] have studied on minimizing the make span and total flow time with discrete particle swarm optimization algorithm and they have suggested that the results can be refine by adding the variable neighborhood search method. Tseng et al. [54] have studied hybrid flow shop scheduling scenario and they have proposed particle swarm optimization algorithm in a new velocity equation form with three different set of velocity equations and they have also compared the results with two other optimization techniques (Genetic Algorithm and Ant colony optimization algorithm). Kashan et al. [55] and Tasgetiren et al. [56] have studied flow shop sequencing and their objective was to minimize the total flow time and make span time of the machines. Multi-objective particle swarm optimization is also one of the common optimization technique used to improve swarm diversity and to eliminate premature convergence and this technique gave better results in relation to minimization of the total weighted flow time, total machine load variation and total weighted tardiness [57-59].

2.6. Harmony Search Algorithm (HSA)

Harmony Search Algorithms was introduced by Geem et al. [60] in 2002 to optimize piping network design. HSA is searching technique base on population which imitates for hormony of the search space. HSA has better power in search space globally and it is simple for implementing in real applications. The important quality of HAS, it identifies the high-performance regions of the search space within a reasonable time.

Zammori et al. [61] have studied with sequence dependent job setup times on one machine and their objective was to minimize the total tardiness penalties and total earliness. Wang et al. [62] considered to study flow shop scheduling problem and they have proposed best harmony search algorithm to minimize make span of the jobs. Gao et al. [63] objective was to minimize total flow time in solving the no-weight flow shop scheduling problems and proposed discrete harmony search algorithm. Yuan et al. [64] have studied for solving flexible job shop scheduling problem and developed hybrid harmony search algorithm to minimize the make span.

3. SUMMARY

The literature shows that the scheduling optimization of identical parallel machines consists of many components with different characteristics. Hence. the optimization of scheduling performance of identical parallel machine scheduling measure and the manufacturing system efficiency becoming tougher. Only the efficient search algorithms, and the desired performance measures of the identical parallel machine scheduling can be improved. Hence, it is necessary to understand and implement to evolve most efficient search heuristic optimization techniques for obtaining satisfactory and nearer-to-optimal solutions. Various researchers are evident that search techniques developed for using various heuristic algorithms which are mention in the above section in this paper. It is also revealed in the literature that the harmony search algorithm is more efficient and effective for minimizing make span and total tardiness among all available optimization techniques in optimization of identical parallel machine scheduling.

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