Minimizing Total Tardiness in Parallel-Machine Scheduling with Release Dates

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ABSTRACT

The considered problem is the scheduling of a set of $N$ jobs on $M$ identical parallel machines in order to minimize the total tardiness without any preemption or splitting. Each job has its own processing time, release date and due date. All the machines are considered identical (with same speed) and available during all the scheduling period. This problem is NP-hard. An exact resolution, an Ant Colony Algorithm (ACO), a Tabu Search (TS) method, a set of Heuristics based on priority rules and an adapted Biskup Hermann Gupta (BHG) method are proposed to solve the problem. The obtained results are discussed and analyzed.

Keywords: Ant Colony Optimization, Business Management, Heuristics, Parallel Machines Scheduling, Release Dates, Tabu Search

INTRODUCTION AND LITERATURE REVIEW

The problem considered here is the scheduling of $N$ jobs, products or services on $M$ identical parallel machines in order to minimize the total tardiness over all the considered load. The jobs are scheduled without any preemption or splitting. Each job has its own processing time, release date and due date. All the machines are identical (with same speed) and available during all the scheduling horizon. Each machine can process at most one job at a time. A job can be processed from the time it is available, i.e., $t \geq r_i$, where $t$ is the system time and $r_i$ is the release time of job $i$. A job is considered as being tardy if its completion time $C_i$ is greater than its due date $d_i$; then its tardiness value is given by $T_i = \max \{C_i - d_i, 0\}$. According to the standard Lawler’s representation (Lawler, 1964) called scheduling three-parameter notation, this problem is quoted as $Pm / r_i / \sum T_i$. In the remainder of the paper the problem will be denoted by $P$.

The jobs and the identical machines are indexed respectively from 1 to $N$ and 1 to $M$. The main characteristics of each job $i$ ($i = 1, 2, ..., N$) are the processing time $p_i$, the release date $r_i$ and the due date $d_i$. A solution or a schedule, which is a unique permutation on the set $(1, 2, ..., N)$, can be constructed by assigning the next unscheduled job in the list to the earliest available machine, ties broken

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by selecting the least indexed machine. A partial schedule is a permutation of a subset of \((1, 2, \ldots, N)\).

The interest for tardiness criterion is due to its practical effect in the real life. This criterion is among the most interesting criteria for production systems, especially in the current situation where competitiveness is becoming more and more intensive. Suppliers do ensure their markets and customers. For that, they must have a high service quality while focusing on delivery dates.

The problem considered here is NP-hard since the problem without release dates is NP-hard (Koulamas, 1994). As mentioned by many authors, the literature is not so rich of works dealing with the parallel-machine scheduling problems with tardiness as objective function. However the situation is not the same for the single machine problem.

Koulamas (1994), Shim and Kim (2008), and some other researchers proposed works giving general view of different researches on the scheduling problems similar or close to the one considered in this paper. The main idea is that there are some papers dealing with the parallel-machine scheduling with makespan or total flow time minimization; interest in the total tardiness minimization as a performance measurement has increased only over the past few years. The following paragraphs in this section are dedicated to summarize works dealing with tardiness criterion and parallel machines shop specifically.

In 1965, Root (1965) developed an algorithm based on a constructive scheme for the case where all the jobs have the same due dates. For the heuristics resolution we could mention the MRM (Montagne’s Ratio Method) (Montagne, 1969) in order to minimize the average tardiness on a single machine. The latter is based on the WI algorithm of Wilkerson and Irwin (1971). To recall, the WI algorithm is based on adjacent pairwise interchange properties. This pairwise technique consists of considering mainly the job with the earliest due date first except when \( t_i + \max(r_i, r_j) > \max(d_i, d_j) \). The considered jobs are \( i \) and \( j \), and \( t_0 \) is the finishing time of the last job in the scheduled list. Dogramaci and Surkis (1979) proposed a heuristic based on three priority rules independently: SPT (Shortest Processing Time), EDD (Earliest Due Date) and minimum slack (the slack of a task \( j \) is defined as \( SL_j = d_j - p_j \)). Ho & Chang (1991) built an assignment rule based on the TPI (Traffic Priority Index). The KPM heuristic of Koulamas (1994), is an extension of single machine heuristic PSK of Panwalkar, Smith and Koulamas (1993) for parallel machine. Koulamas (1997) proposed a method called PDEC based on the method of Potts and Wassenhove (1991) for the single machine problem and the HSA (Hybrid Simulated Annealing) heuristic based on simulated annealing. Mention should also be made of the HPJF (Highest Priority Job First) method of Chen, Wong, and Ho (1997) based on the WI algorithm recalled above. In HPJF, the principal is to get the initial partition of jobs based on EDD, then the jobs are scheduled on machine using WI. Alidaee and Rosa (1997) proposed a heuristic which is an extension of the MDD method (Modified Due Date) of Baker and Bertrand (1982). Armentena and Yamashita (2000) dealt with the problem \( Pm / / \sum T_j \) using a tabu search (TS) algorithm. They hybridized TS with some diversification strategies based on the insert moves or swap ones. In 2004, Bilge, Kirca, Kurtulan, and Pekgün (2004) proposed a Tabu Search algorithm for the problem \( Pm / r_j, S_{mj} / \sum T_j \) where jobs have sequence dependent setup times, distinct due dates and release dates. The proposed TS is claimed by the authors to be robust because of special candidate list strategies, tabu classifications, tabu tenure and intensification/diversification strategies. This method will be detailed below since an adaptation is employed to solve the problem \( P_.\) Anghinolfi and Paolucci (2007) proposed a metaheuristic (HMH) which integrates several features from TS, simulated annealing (SA) and variable neighborhood search (VNS). HMH is based on the definition of solution neighborhoods and moves. HMH generates a list of candidates based on CLS.
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