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Minimizing total earliness and tardiness through unrelated parallel machine scheduling using distributed release time control

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ABSTRACT

Using unrelated parallel machine scheduling to minimize the total earliness and tardiness of jobs with distinct due dates is a nondeterministic polynomial-hard problem. Delayed customer orders may result in penalties and reduce customer satisfaction. On the other hand, early completion creates inventory storage costs, which increase the total cost. Although parallel machines can increase productivity, machine assignments also increase the complexity of production. Therefore, the challenge in parallel machine scheduling is to dynamically adjust the machine assignment to complete the job within the shortest possible time. In this paper, we address an unrelated parallel machine scheduling problem for jobs with distinct due dates and dedicated machines. The objective is to dynamically allocate jobs to unrelated parallel machines in order to minimize the total earliness and tardiness time. We formulate the problem as a mixed integer linear programming (MILP) model and develop a modified genetic algorithm (GA) with a distributed release time control (GARTC) mechanism to obtain the near-optimal solution. A preliminary computational study indicates that the developed GARTC not only provides good quality solutions within a reasonable amount of time, but also outperforms the MILP model, a classic GA and heuristic approaches described in the literature.

1. Introduction

Toyota's just-in-time (JIT) system is an effective operations management approach in the manufacturing industry. The prevalence of JIT highlights problems concerning the earliness and tardiness of job completion. Delayed delivery may negatively influence customer satisfaction and company reputation and generate penalties, whereas early job completion may increase inventory storage costs. Therefore, companies have aimed to minimize the earliness and tardiness of job completion while achieving their goals and maximizing benefits [1].

In addition to due date constraints, various on-site production constraints must be considered when addressing scheduling problems. The production capacity of a manufacturing site is generally limited by machines that cause bottlenecks in the production system. Manufacturers typically employ additional machines to relieve these bottlenecks. Although using more machines can increase productivity, machine assignments also increase the complexity of production. The production efficiencies of new and used machines differ, and may cause production time discrepancies for similar products, resulting in an unrelated parallel machine scheduling problem [2], which is classified as a nondeterministic polynomial-time (NP) hard problem. The challenge in unrelated parallel machine scheduling is dynamically adjusting the machine assignment to complete the job within the optimal amount of time so as to minimize earliness and tardiness.

In the present study, we examine the various limitations of unrelated parallel machine scheduling, such as dedicated machines and varying due dates for jobs. In addition, we combine a genetic algorithm with a distributed release time control (GARTC) mechanism to plan machine selection and job processing sequences, thereby minimizing the total earliness and tardiness of job completion. We subsequently develop a problem according to the integer programming model and establish a scenario for testing and verifying the performance of the mathematical model and the proposed algorithm.

This paper is divided into six sections. In Section 2, we review literature related to unrelated parallel machine scheduling and minimizing the total earliness and tardiness of job completion. We describe the problem and present the mathematical model in Section 3. In Section 4, we describe the proposed release time control and its composition. We present the near-optimal solu-

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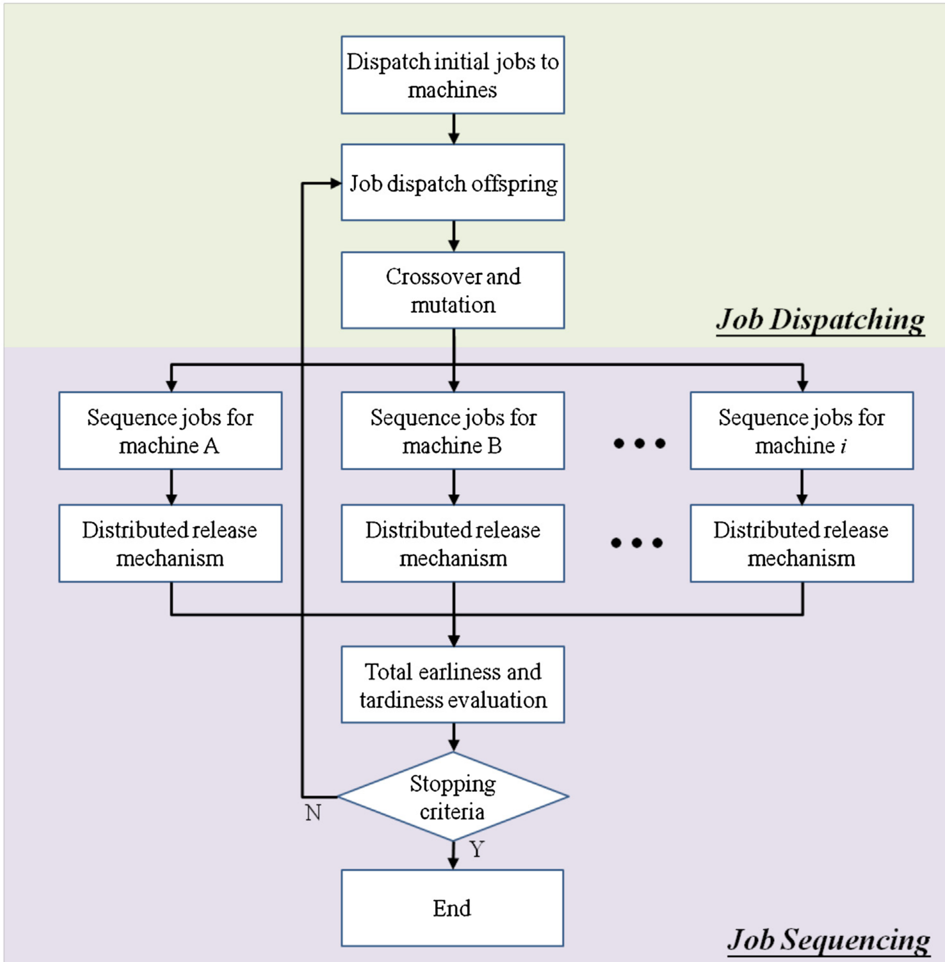

Fig. 1. Distributed genetic algorithm process flow.

tions obtained from GARTC and compare its performance against the mixed integer linear programming (MILP) model, a genetic algorithm (GA) and a parallel machine–moving block heuristic (PM–MBH) algorithm in Section 5. In Section 6, we discuss contributions and make recommendations for future research before concluding with some final remarks.

2. Literature review

Machine scheduling can be divided into single machine and parallel machine scheduling [3]. Single machine scheduling involves employing a single machine to process all components. In parallel machine scheduling, inconsistencies in production output are primarily attributed to differences in machine performance. Thus, parallel machine scheduling can be subdivided into the following categories according to machine performance [4]:

(1) Identical machine scheduling: The functions and speeds of all machines employed in a production process are identical. In other words, the processing time required to complete a job is the same for all machines.
(2) Uniform machine scheduling: The processing time of a job varies for different machines depending on the rate parameters of each machine.
(3) Unrelated parallel machine scheduling: The processing time of a job varies for different machines, thus causing non-uniformity in production. In this type of scheduling, jobs are dispatched to different machines in order to increase efficiency. Thus, unrelated parallel machine scheduling processes are extremely complex. The problem examined in the present study is included in this category.

However, solving large scale problems with such models is time consuming and may produce only local optimal solutions. Rapid development of computing technology enabled the genetic algorithm (GA), a search heuristic based on Darwin's theory of evolution, to be maximized using the high speed computation capability of computers. The GA uses natural evolution techniques, such as crossover and mutation, to effectively determine near-optimal solutions based on full-scale searches. Thus, the GA is often employed to solve large-scale, complex integer programming problems.

The most commonly used performance measures include maximum tardiness [5], mean tardiness [5], total weighted tardiness and earliness [6], and the number of delayed jobs [7]. These have been extended to parallel machine and unrelated parallel scheduling. Lin, Ying, Chiang and Wu [8] minimized total weighted earliness and tardiness penalties on parallel machines for jobs with a common due date. M'Hallah and Al-Khamis [9] investigated minimum weighted earliness and tardiness using a parallel machine scheduling problem for jobs with distinct due dates. Polyakovskiy and M'Hallah [10] developed a heuristic based on a multi-agent system to solve weighted earliness and tardiness problems using parallel machine scheduling with various processing times and distinct due dates. Numerous researchers have attempted to resolve parallel machine problems using various heuristic methods, including