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Solving distributed FMS scheduling problems subject to maintenance: Genetic algorithms approach

Felix T.S. Chan[a,*], S.H. Chung[a], L.Y. Chan[a], G. Finke[b], M.K. Tiwari[c]

[a]*Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong*
[b]*LEIBNIZ—IMAG, University Joseph Fourier, France*
[c]*Department of Manufacturing Engineering, National Institute of Foundry and Forge Technology, India*

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Abstract

In general, distributed scheduling problem focuses on simultaneously solving two issues: (i) allocation of jobs to suitable factories and (ii) determination of the corresponding production scheduling in each factory. The objective of this approach is to maximize the system efficiency by finding an optimal planning for a better collaboration among various processes. This makes distributed scheduling problems more complicated than classical production scheduling ones. With the addition of alternative production routing, the problems are even more complicated. Conventionally, machines are usually assumed to be available without interruption during the production scheduling. Maintenance is not considered. However, every machine requires maintenance, and the maintenance policy directly affects the machine's availability. Consequently, it influences the production scheduling. In this connection, maintenance should be considered in distributed scheduling. The objective of this paper is to propose a genetic algorithm with dominant genes (GADG) approach to deal with distributed flexible manufacturing system (FMS) scheduling problems subject to machine maintenance constraint. The optimization performance of the proposed GADG will be compared with other existing approaches, such as simple genetic algorithms to demonstrate its reliability. The significance and benefits of considering maintenance in distributed scheduling will also be demonstrated by simulation runs on a sample problem.

Keywords: Distributed scheduling; Flexible manufacturing systems; Genetic algorithms; Maintenance

1. Introduction

The significance of distributed scheduling (DS) has been recognized by many researchers and industrialists in recent years because of the changes in the mode of today's production environment. Single factory production in traditional manufacturing has been gradually replaced by multi-factory production due to the trend of globalization. These factories may be geographically distributed in different locations, which allow them to be closer to their customers, to comply with the local laws, to focus on a few product types, to produce and market their products more effectively, and to be responsive to market changes more quickly [1,2]. Each factory is usually capable of manufacturing a variety of product types. Some may be unique in a particular factory, while some may not. In addition, they may have different production efficiency and various constraints depending on the machines, labor skills and education levels, labor cost, government policy, tax, nearby suppliers, transportation facilities, etc. This induces different operating costs, production lead time, customer service levels, etc. in different factories [3–6].

DS problems are much more complicated than the scheduling problems in single factory. In general, it mainly involves two issues: (i) allocation of jobs to suitable factories and (ii) determination of the production scheduling in each factory [3,7]. Once a job is allocated to a factory and processed, it is usually unable or uneconomical to transfer this work-in-progress part to another factory for the remaining operations. Since production scheduling depends on the job allocation results, the total operating

*Corresponding author. Tel.: +2859 7059; fax: +2858 6535.
E-mail address: ftschan@hkucc.hku.hk (F.T.S. Chan).

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cost, makespan, order fulfillment, etc. will be different. The complexity of the problem greatly increases.

At production level, machine maintenance is inevitable. It directly influences the production rate, product quality, machine availability, utilization ratio, etc. If the production schedule obtained from DS does not consider maintenance, the planning determined will be seriously interrupted because of the mismatch among various processes. Consequently, the system reliability will be damaged and the purpose of DS will not be achieved.

The objective of this paper is to propose a new idea named genetic algorithms with dominant genes (GADG) to deal with DS problems subject to machine maintenance constraint. The function of the dominant genes (DGs) is to identify and record the best genes and the corresponding structure in the chromosome. A new encoding of chromosome is also specially designed to deal with the machine maintenance constraint. This paper is divided into the following sections. Section 2 gives a literature review. Section 3 presents the DS problem subject to preventive maintenance. Section 4 presents the proposed DGs, and its crossover mechanism. Section 5 analyzes and discusses the performance of the DGs. Section 6 shows the significance of considering maintenance in DS. Lastly, the paper is concluded in Section 7.

2. Literature review

The main purpose of DS is to maximize the system reliability and the resources utilization through collaboration among different supply chain activities. Distributed systems can be considered as a set of processes which have to be executed in different nodes (locations), and subject to various constraints such as time, capacity, tooling, etc. [8–11]. Each entity has to share the available resources and collaborate with each other in order to achieve the objective. The task scheduling problem consists of defining a schedule that can meet all timing and logical constraints of the tasks being scheduled, and in general, it has been classified as NP-complete [12].

DiNatale and Stankovic [13] applied simulated annealing algorithm to distributed static systems, in which tasks are periodic and have arbitrary deadlines, precedence, and exclusion constraints. They present a general framework consisting of an abstract architecture model and a general programming model. Recently, Jia et al. [3,14] have proposed a modified genetic algorithm (GA) to solve DS problems. They proposed an encoding of chromosome, crossover mechanism, and two mutation mechanisms. Their modified GA has been compared with other classical scheduling approaches and obtained satisfactory results. However, their chromosomes are designed for fixed production routing. For alternative production routing, Chan et al. [15] proposed a new encoding mechanism. They also proposed a DGs approach, which demonstrated its ability to enhance the optimization reliability. There are many other heuristic approaches that can be found in Barroso et al. [7], Santos et al. [16], Tindell et al. [17], etc. However, in the knowledge of the authors up to this moment, there is a lack of paper which takes account of machine maintenance in DS.

Maintenance policy influences the machine availability and the machine utilization ratio. The purpose of maintenance management is to reduce the effect of breakdown and maximize the facility availability at minimum cost [18–20]. Machine age is an important measurement in maintenance because it affects the inspection time, repairing time, production rate, product quality, failure rate, etc. After each time of maintenance, the machine age has to be adjusted. It will then again induce a new set of inspection time, repairing time, production rate, and product quality [21,22]. Kenne and Boukas [23] proposed a two-level hierarchical control model to deal with the production and preventive maintenance planning control problem for a multi-machine FMS. Chan et al. [24] also proposed a total productive maintenance (TPM) methodology for an electronic manufacturing company, aiming to increase the availability of the existing equipment.

Applying pure mathematical optimization approach to determine an optimal solution may not be efficient. In many cases, scheduling problems are classified as NP-hard. Therefore, applying heuristic methodology to obtain a near optimal solution in a relatively shorter period is more appreciated and practical. Among different heuristic approaches, GAs are recognized as an appropriate and efficient approach. Many references can be found. For example, Cheung et al. [25] gave a detailed tutorial survey on papers using GAs to solve classical Job-Shop scheduling problems (JSP) in their Part I survey. In Part II, they reviewed papers using hybrid GA to tackle JSP [26]. Jain and ElMaraghy [27] proposed a GA to solve single process plan scheduling (SPPS) problems. Cavalieri and Gaiardelli [28] applied a hybrid GA, which combines GA with dispatching rule (Earliest Due Date), to solve multi-objective scheduling problems. Sakawa [29] combined GA with fuzzy logic to model the uncertainties of production lead time and order due date in scheduling problems. More references can be found, for example, Mori and Tseng [30], Jawahar et al. [31], Ghedjati [32].

To strategically strengthen the genetic search in different phases of evolution, many researchers proposed different kinds of Adaptive GAs for their particular problems. During the genetic evolution, the genetic parameters, such as population size, crossover rate, and mutation rate will change strategically [28,33,34]. Michalewicz [33] proposed a non-uniform mutation which allows the operator to search through the solution space uniformly in the beginning stages to prevent prematurity of the solution pool, and then locally in the later stages for fine local tuning. González and Fernández [34] adopted a dynamic population size approach to replace the old chromosomes with new ones to maintain the diversity of solution pool.