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Hybrid evolutionary algorithm-based real-world flexible job shop scheduling problem: application service provider approach

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Abstract

This paper presents an approach for scheduling of customers' orders in factories of plastic injection machines (FPIM) as a case of real-world flexible job shop scheduling problem. The objective of discussed work is to provide FPIM with high business speed which implies (a) providing a customers with convenient way for remote online access to the factory's database and (b) developing an efficient scheduling routine for planning the assignment of the submitted customers' orders to FPIM machines. Remote online access to FPIM database, approached via delivering the software as a Web-service in accordance with the application service provider (ASP) paradigm is proposed. As an approach addressing the issue of efficient scheduling routine a hybrid evolutionary algorithm (HEA) combining priority-dispatching rules (PDRs) with GA is developed. An implementation of HEA as a database stored procedure is discussed. Performance evaluation results are presented. The results obtained for evolving a schedule of 400 customers' orders on experimental model of FPIM indicate that the business delays in order of half-an-hour can be achieved.

Keywords: Flexible job shop scheduling; Priority dispatching rules; Evolutionary algorithm; Application service provider

1. Introduction

Until recently, the role of the production factories had been associated with the manufacturing of a high volume of low-cost and high-quality goods. However, an evolution of these features is lately observed as a result of the recently emerged trend in the major world's economies of decreasing the rate of economic growth. Still maintaining the importance of producing low-cost and high-quality goods, the relevance of the high manufactured volume is going to be gradually replaced by the role of the high business speed—the

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ability to react quickly in submitting and modifying the customers' orders. The high business speed implies that factories should provide the customers with services such as remote submission of orders in operative mode; prompt feedback allowing for customers' awareness of the anticipated due dates of their orders as well as awareness of the expected ratio of tardy orders and their respective delays; and services providing the ability to promptly follow the current state of the customers' orders.

Within this context, the objective of our research is to investigate the feasibility of developing a scheduling system for factories of plastic injection machines (FPIM), emphasizing on providing the mentioned above customers services needed for achieving factory's high business speed. Fulfilling our objective implies addressing of the following two main tasks. First, allowing for submission of orders and tracking their statuses requires providing a convenient way for remote online access to the factory's database. And second, allowing for prompt customers' awareness about the anticipated due dates of their orders assumes developing of efficient (both in terms of runtime and quality of solution) scheduling routine for planning the assignment of the submitted customers' orders to the factory's equipment. Our work is intended to address these main tasks, and its contents could be viewed from three different aspects, representing the following three layers of abstraction of the developed scheduling system:

- Problem aspect—the task from the specific problem domain intended to be solved.
- Aspect of algorithmic paradigm—the algorithmic paradigm employed to solve the problem.
- Implementation aspect—the system architecture used to solve the considered problem exploiting the adopted algorithmic paradigm.

The discussion, presented in this document, is attempting to highlight these aspects of our work, and the remaining of the paper is structured as follows. Section 2 briefly explains the problem aspect—a real-world problem of scheduling of factories of plastic injection machines (FPIM) as an instance of the class of flexible job shop scheduling problem (FJSS). Section 3 discusses the aspect of algorithmic paradigm—the main attributes of the hybrid evolutionary algorithm, we developed to solve the targeted FPIM FJSS. Section 4 considers the implementation aspect—the application service provider (ASP) approach, focusing on developing of three-tiered Web-based system architecture. Performance evaluation results are given in Section 5. Finally, Section 6 draws a conclusion and discusses some directions for future work.

2. Real-world case of injection machines scheduling

The FPIM FJSS problem consists of a finite set of orders to be processed on a finite set of machines. Each order specifies the amount of just one good from the finite set of goods, produced by the factory. Each good can be produced using any of currently available molds from the finite set of mold instances of at least one of the finite set of the available mold types. Each mold type can be attached to at least one machine from the available finite set of machines. The one-to-many relationship between the goods and molds and between the molds and the machines implies that any order can be processed in at least one machine. In general, processing the order on specified machine is preceded by the set-up phase, needed to attach the required mold (if mold of the current order differs from the mold of the previous one) and to change the resin (if needed). Analogically, the processing of the order might be followed by completion phase, required to remove the mold in case that the next scheduled order requires an attachment of different mold type.

The capacity *constraints* specify that each mold can be attached to just one machine at a time and each machine can attach just one mold. Consequently, a machine can process only one order and each order can be processed by only one machine at a time. An additional constraint stipulates that the amount of the molds of specified type is limited; therefore an order can be processed only if the required mold is currently available. Also, the machines can be suspended for scheduled maintenance and for daily operation breaks. The order cannot be preempted by another order, however, depending on the specified machine operation mode, the orders, started before the suspension time should be interrupted upon the commencing the maintenance interval or might be allowed to complete