Guided restarting local search for production planning

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ABSTRACT
Planning problems can be solved with a large variety of different approaches, and a significant amount of work has been devoted to the automation of planning processes using different kinds of methods. This paper focuses on the use of specific local search algorithms for real-world production planning based on experiments with real-world data, and presents an adapted local search guided by evolutionary metaheuristics. To make algorithms efficient, many specifics need to be considered and included in the problem solving. We demonstrate that the use of specialized local searches can significantly improve the convergence and efficiency of the algorithm. The paper also includes an experimental study of the efficiency of two memetic algorithms, and presents a real-world software implementation for the production planning.

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1. Introduction

Planning problems exist in many real-world-industrial production settings and can be solved with a large variety of different approaches. Due to the growing complexity of these real-world planning problems, significant work has been devoted to the automation of planning processes using different kinds of methods. Furthermore, as a result of the increasing deployment of planning and scheduling systems, we often have to deal with very large search spaces, real-time performance demands, and dynamic environments (Nareyek, 2000). A review of the research on integrated process planning and scheduling, along with a discussion on the extent of the applicability of various approaches is presented in Li et al. (2010) and Shaotan et al. (2010). This paper focuses on the use of specific local search algorithms for real-world production planning based on experiments with real-world data and presents the adapted, local search, evolutionary-based metaheuristics for the real-world industrial problem. It also includes an experimental study of the efficiency of two memetic algorithms, and presents a real-world software implementation for the production planning.

The motivation of this research is to solve an industrial problem. The goal of our real-world production-planning problem is to find a production plan that satisfies the production time constraints and minimizes the production costs. This involves many specific constraints that need to be considered. The main problem is the exchange delay, caused by adapting the production lines to different types of products and supplying the appropriate parts. Namely, the manufacturing processes of multiple types of products require many different steps and different product parts for the completion of each product type. Such a kind of problem can be represented as a job shop scheduling problem (Brucker, 1998).

For solving scheduling problems, many scheduling methods are reported in the literature (Xing et al., 2010; Wang and Tang, 2009; Guo et al., 2009; Chiong and Dhakal, 2009; Jarboui et al., 2009). One of the nature-inspired approaches (Chiong, 2009) is the genetic algorithm (GA). A heuristic for the open job shop scheduling method based on the GA was developed by Senthilkumar and Shahabudeen (2006). On the other hand, a scheduling method based on the GA was developed by considering multiple criteria in Chryssolouris and Subramaniam (2001). Other implementations of the GA for scheduling can be found in Vazquez and Whitley (2000).

The advanced local search approaches are usually guided by evolutionary algorithms, simulated annealing, tabu search, min-conflicts, and others (Voß, 2001). The basics of local search are in the successive changing of solutions with moves that alter solutions locally. These moves are defined by the neighborhood, which contains all the solutions that can be reached with one move/change. As the solution quality of the local optima may be unsatisfactory, we need some mechanisms that guide the search to overcome the local optimality. A simple strategy is to iterate/restart the local search process after a local optimum has been obtained, while more structured ways, e.g., the use of an evolutionary search, to overcome the local optimality might be advantageous. In Hamiez and Hao (2001), the problem of sports-league scheduling is addressed, presenting the results achieved by a tabu search method based on a neighborhood of value swaps. Furthermore, some works deal with planning systems that are able to
incorporate resource reasoning. In Chien et al. (2001) the re-planning capabilities of local search methods in a continuous planning process clearly outperform a restart strategy. In Engelhardt and Chien (2001), learning is used to speed up the search for a plan, where the goal is to find a set of search heuristics that guide the search, while Knight et al. (2001) proposes a technique for aggregating single search moves, so that distant states can be reached more easily.

GAs in combination with local search procedures are known as memetic algorithms (MAs) (Ong and Keane, 2004). They represent a synergy of the evolutionary approach with separate individual learning or local improvement procedures (local searches) for the problem search. Various MAs were developed (Hasan et al., 2009; Caumont et al., 2008; García-Martínez and Lozano, 2008; Siarry and Michalewicz, 2008; Ombuki and Ventresca, 2004) to obtain even better results than the GA for various scheduling applications. With the use of local search techniques the results were further improved. MAs do not only improve the quality of the solutions, but they also reduce the overall computational time (Hasan et al., 2009). Special attention should also be given to the dynamic nature of the production. Local search is well suited for anytime requirements (Nareyek, 2000). Here, a variety of algorithms have been proposed to solve dynamic optimization problems (Moser and Chiong, 2010; Tfaili and Siarry, 2008; Engelhardt and Chien, 2001).

The rest of the paper is organized as follows: in Section 2, we describe the problem and give its mathematical formulation; in Section 3, we present preliminary evaluations for the algorithm selection; in Section 4, we describe the evolutionary algorithms; in Section 5, we introduce the used local search procedures; in Section 6, we show the integration of guiding evolutionary algorithms with local search procedures; in Section 7, we present the experimental environment and the results of the evaluation with the real-world data; in Section 8, we present the implemented application for automatic production planning; and in Section 9, we conclude and propose possible future work.

2. Production planning problem

The planning problem was introduced while designing the application for planning and monitoring of the production in the company ETA Cerfnko d.o.o. The company produces components for domestic appliances, including hot plates, thermostats, and heating elements.

Among the various production stages, the most demanding was the production of cooking hot plates. Namely, the production of the components and parts for all the types of plates is more or less similar, but the standard plate models of the current range differ in size (height, diameter), connector type and power characteristics (wattage). There are so many different models due to the large number of orders. The number of delayed orders, exchange delays and the time to finish all the orders is

\[ N = \sum_{k=1}^{n} |O_k|. \]

A schedule is denoted by

\[ C = S_{12}S_{21}S_{22} \cdots S_{1N}S_{N2}, \]  

where \( g_{k1} \) is an index on some operation \( o_k \in O_1 \cup \cdots \cup O_n \) and \( g_{k2} \) is the production line used to perform the operation \( o_k \), for every \( k \in \{1,2,\ldots,N\} \). In the following, we use the notation of index \( g_{k1} \) and operation \( o_k \) interchangeably. Furthermore, let \( F(o_k) \) denote a finishing time of the operation \( o_k \) and let \( exdL(o_k) \) denote the exchange delay caused by the exchanging of operation \( o_k \) for the operation \( o_k \) on the production line \( M_l \), for \( o_k, o_k \in O_1 \cup \cdots \cup O_n \). The task is to find the schedule that minimizes the number of delayed orders, exchange delays and the time to finish all the orders. The number of delayed orders \( n_{\text{orders}} \) is

\[ n_{\text{orders}} = \sum_{i=1}^{n} \text{delay}_i. \]
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