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A comparative study of a new heuristic based on adaptive memory programming and simulated annealing: The case of job shop scheduling

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Abstract

In this study, a general framework is proposed that combines the distinctive features of three well-known approaches: the adaptive memory programming, the simulated annealing, and the tabu search methods. Four variants of a heuristic based on this framework are developed and presented. The performance of the proposed methods is evaluated and compared with a conventional simulated annealing approach using benchmark problems for job shop scheduling. The unique feature of the proposed framework is the use of two short-term memories. The first memory temporarily prevents further changes in the configuration of a provisional solution by maintaining the presence of good elements of such solutions. The purpose of the second memory is to keep track of good solutions found during an iteration, so that the best of these can be used as the starting point in a subsequent iteration. Our computational results for the job shop scheduling problem clearly indicate that the proposed methods significantly outperform the conventional simulated annealing.
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Keywords: Simulated annealing; Tabu search; Adaptive memory programming; Meta-heuristics; Job shop scheduling

1. Introduction

Since the early 1980's, a growing interest has been developing in meta-heuristics as a tool to tackle combinatorial optimization problems. Among the earliest and the most popular algorithms that have attracted much attention are tabu search (Glover, 1986), simulated annealing (Kirkpatrick et al., 1983), and genetic algorithms

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(Holland, 1975). In its basic form, tabu search explores exhaustively the neighbourhood of a solution. Two solutions are said to be 'neighbours' if one can be obtained by means of a well-defined modification of the other. The costs of neighbouring solutions are compared, and the neighbour with the lowest cost value is selected. This new solution becomes the initial solution in the next iteration. At the end of each iteration, the entire solution, or a part of thereof, is added into a tabu list to prevent it from being revisited for a specific number of iterations. Advanced forms of the algorithm have been also developed to solve combinatorial optimization problems. In general, these versions of the algorithm have been designed specifically to deal with problems such as quadratic assignment problem (Taillard, 1991), vehicle routing problem (Barnes and Carlton, 1995; Taillard et al., 1997), flow shop scheduling problem (Nowicki and Smutnicki, 1996), and job shop scheduling problem (Taillard, 1994; Barnes and Chambers, 1995; Dell' Amico and Trubian, 1993).

Simulated annealing is a stochastic local search technique based on principles of physics. In its basic form, the algorithm begins to search the solution space by selecting a neighbour from the neighbourhood of an initial solution. A neighbouring solution could be generated by perturbation in the current solution. In simulated annealing, a neighbouring solution is generated randomly. The cost value of the candidate solution is compared with that of the current solution. If the candidate solution improves the quality of the current solution, it is accepted and a move is made. Otherwise, a transition probability function will be used to determine whether to accept or to reject the candidate solution. If the value of the transition probability is greater than a random number (generated from a uniform distribution), then the candidate solution, despite being worse than the current one, is accepted. If the transition to the candidate solution is rejected, another solution from the neighbourhood of the current solution will be selected and evaluated.

In conventional simulated annealing the search begins with a high value of transition probability allowing the search to accept even worse solutions. However, as the search continues, the chance of accepting solutions with poor quality reduces. During the search, the declining rate of transition probability is controlled by a parameter known as *annealing schedule* or *cooling schedule*. Simulated annealing, both in its basic form and in hybrid with other heuristics, has been successfully applied to many combinatorial optimization problems such as job shop scheduling (Van Laarhoven et al., 1992), flow shop scheduling (Osman and Potts, 1989; T'kindt et al., 2002), and vehicle routing (Osman, 1993).

A number of new meta-heuristics have been also developed in recent years. Some examples of those algorithms are Greedy Randomized Adaptive Search Procedure (GRASP) (Feo and Resende, 1995; Aiex et al., 2003), Adaptive Multi Start (AMS) (Boese et al., 1994), and Ant System (Colorni et al., 1992a,b). Ant system has been developed based on the way ants communicate with each other as they search for food. Real ants search around their nest for food in a random fashion. Once an ant finds a source of food, it leaves on its way back to the nest a trail of chemical instance called *Pheromone* to guide other ants to the source of the food. After a while, the path to the closer source of the food becomes more highlighted by large amount of pheromone trail. Ant system was proposed to solve combinatorial optimization problems. It represents ants by "*agents*" to construct a provisional solution iteratively. To construct the solutions, ants are guided by artificial pheromone trail and other problem information. Once the solutions are constructed, the ants deposit pheromone on the components that they have used in their solutions. In general, those components that contributed in generating a good solution or they have been used by more ants receive higher amount of pheromone. It is worth to note that before reinforcing the pheromone trails, the level of all pheromone is weakened to avoid the search getting trapped. Using different ways to update the pheromone has generated different ant system algorithms (Taillard et al., 2001; Gambardella and Dorigo, 1996; Stutzle and Hoos, 2000). Also, it has been demonstrated that a hybrid ant system with a local search provides better results in solving complex problems

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