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ScienceDirect
Engineering Applications of Artificial Intelligence 21 (2008) 1101–1112
Engineering Applications of ARTIFICIAL INTELLIGENCE
www.elsevier.com/locate/engappai

A study of project scheduling optimization using Tabu Search algorithm

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Received 20 November 2006; received in revised form 19 April 2007; accepted 18 November 2007
Available online 26 December 2007

Abstract

The research will focus on investigating a more efficient alternative to solve resource-constrained project scheduling problems (RCPSP). Also, instead of using traditional Tabu Search (TS) algorithm and the other Artificial Intelligence (AI)-based heuristic approaches, this research develops an improved TS model by modifying the way of finding a starting solution instead of traditional TS algorithm to solve the problems described above. The model can effectively provide better results in reducing project duration for solving RCPSP compared to traditional TS-based search techniques and Artificial Intelligence (AI)-based approaches. The paper suggests the optimum parameters' setting values for the models the paper presented through sensitivity analysis to obtain better solution quality more easily. Also, the method the paper presented provides a good user interface linking with existing commercial software systems to help for the practitioner in the application of project management in the real world.

Keywords: Multi-resource project scheduling; Project management; Tabu Search; Optimization; Heuristic methods

1. Introduction

The process of project planning includes the activities making up the project are defined, and time and resource estimation for the activities in the project are made. Next, scheduling the project considering resource supply will be one of the most important tasks in project management. After the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) were developed successively, the project resource-scheduling problem was subject to more attention. Resource-constrained project scheduling problems (RCPSP) involve assigning a resource or set of resources to jobs (activities) in the project with limited resource (capacity) in order to meet some predefined objective (Yang et al., 2001). In the RCPSP, the activities of a project have to be scheduled as the duration of the project is minimized. Therefore, to accomplish the activities of the project, the technological precedence constraints and the availability of the renewable resources should be considered.

RCPSP is NP (Non-deterministic Polynomial-time)-Hard. In the early stage, during solving of the RCPSP, most researchers and practitioners still used to utilize the heuristic rule to solve this problem. It was found that the solution of searching speed and accuracy was sometimes not good (Boctor, 1990; Chan et al., 1996; Davis, 1973). Therefore, finding a way to obtain a near optimal solution efficiency without sacrificing the solution quality is an important issue to investigate in attempting to solve the RCPSP. Tabu Search (TS) was first presented by Glover et al. (1995) and was applied in solving the integer programming. It is a solution-search algorithm that can conquer area optimization by guiding area search. Thus, TS algorithm, a tool to solve the optimization problem, could be applied in this research to solve the RCPSP. TS algorithm has been proven to get good results for solving combinatorial optimization in many areas. Sometimes, it can obtain a better solution quality than some heuristic algorithms in some specific problems. This study will implement the TS concept as basis to develop a new algorithm to solve RCPSP in construction projects.

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0952-1976/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engappai.2007.11.006

2. RCPSP algorithm

Considering the constrained resources, there are two objectives of the project scheduling: (1) to make resource utilization of the project efficient in order to reduce the possibility of delay in the project when the resource is limited and (2) to make resource utilization of the project more effective in order to achieve a predefined objective, for example, a better financial management performance (Yang et al., 2001).

Yang et al. (2001) summarize past work in resource-constrained project scheduling problems (RCPSP), separate the RCPSP into six different classes and also present a new RCPSP with a specialized minimum cost objective function. Davis (1973) showed that RCPSP could be solved by using two mathematical models, such as Linear Programming (LP) and Dynamic Programming (DP) to analyze a problem and obtain the optimal solution. However, there were shortcomings in the solving of the large-scale problems. Although one could get the optimal solution, the heavy and complex process of solution searching made it inefficient (Davis, 1973). According to Wiest's study, the 0–1 integer programming was used to establish a problem with 55 activities and four kinds of resource types, which, in this problem, required 1650 decision variables and 6870 restrict equations (Wiest, 1963). Furthermore, there are easily hundreds of activities in the actual environment which would make it almost impossible to solve this problem and achieve the optimal solution. Therefore, in recent years, some researchers have presented new algorithms for the related studies of the RCPSP to improve the shortcomings of traditional approachs which is summarized as follows.

Karaa and Nasr (1986) and Savin et al. (1996, 1998) implemented neural networking (NN) in solving construction resource leveling. The objective of the model presented in their research was to make the resource requirements as smooth as possible. Boctor (1990) and Padilla and Carr (1991) implemented heuristic methods that produced feasible solutions efficiently, which were, however, not necessarily optimal. Chan et al. (1996) proposed an algorithm using genetic algorithm (GA) in solving the RCPSP. Yang and Ye (1996) applied constraint programming to solve this problem and made tests for different objectives. These objectives were reached with the shortest completion time and the lower cost (Yang and Ye, 1996). Hegazy (1999) also presented an optimization model using GAs solving RCPSP. Leu and Yang (1999) solved the RCPSP using GA based on a fuzzy optimal model. The model took into consideration both uncertain activity duration and resource constraints of the project. Senouci and Adeli (2001) presented a mathematical model for solving both RCPSP and simultaneously project total cost minimization.

Various modern heuristic algorithms have recently been developed. There are comprehensive, related researches within the other industry's field, obtaining valuable achievements. Since the proposed approach in this paper utilizes TS, a brief description of some necessary background is provided as follows.

The related study that the TS approach was applied to in regard to scheduling optimization also had some achievements. Thomas and Salhi (1998) presented an approach which uses well-defined move strategies and a structured neighborhood, defines appropriate Tabu status and tenure and takes account of objective function approximation to speed up the search process. Valls et al. (1998) presented, when the TS approach was applied to the standardization scheduling optimization under the condition of a batch of activities, procedures and resources of two simple and paralleled standardizations. Its objective is to minimize the required time for scheduling. Vinicius and Debora (1999) applied the TS approach into the scheduling problem to search the minimal total delay, while many scholars utilized the minimal total delay production span and multi-activities scheduling in the small-size shop grouping. Al-Turki et al. (2001) utilized the TS approach to solve the typical single machine scheduling problem, the non-regularity performance measurement and the minimal change problem, when the minimal completion time difference and the performance could be achieved from the common reduced time interval. Gopalakrishnan et al. (2001) applied the heuristic TS approach in preventive maintenance scheduling, and utilized the TS approach to solve the preventive maintenance scheduling problem and speculate the maximum priority, whereby the objective of the task scheduling was to obtain the average restrained resources. Hurink and Knust (2002) applied the TS approach to schedule a single robot in an outsourcing small-size shop environment, utilizing the structure of the neighborhood solution of the TS approach to solve the scheduling problem. In this case, the objective was to determine the sequence of nodes so as to obtain the minimal waiting time. Based on a review of related papers, it can be observed that, for the resource-scheduling problem, in recent years, many researchers have presented new analysis and algorithm and have obtained distinguished results. The TS approach has been widely applied to solve various kinds of combinatorial optimization problems in the industrial engineering area and other areas.

3. TS-based resource-scheduling model

The structure and the algorithm of the TS approach will be introduced in the following sections.

3.1. Elements of the TS approach

The main elements of the TS approach can be divided into the following six items, which are described as follows:

(1) Starting Solution

First of all, it is necessary to generate a feasible solution from the problem, namely, Starting Solution, which is generally obtained by using the heuristic rule.