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Constraint-based schedule repair for product development projects with time-limited constraints

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Abstract

In today's changing marketplace, accurate project planning and scheduling for product development becomes difficult. It is important for an R&D organization to quickly recognize the impact of unexpected events and rapidly reschedule product development projects. In addition, it has become more important for a firm to meet the due date requirement for a product development project than to satisfy the available resource capacity, since a late project will incur a great sales loss or a large amount of penalty to customers. This paper models the scheduling of product development projects as a dynamic constraint satisfaction problem, where the due date constraint is considered as a "hard" constraint that cannot be violated. All unexpected changes during the product development are regarded as additions or deletions of constraints to the problem. A reactive scheduling methodology based on the meta-heuristic approaches is developed to repair a disrupted schedule with the minimum cost of resource conflicts. The proposed approaches have been tested on several benchmark problems and satisfactory results have been obtained.

Keywords: Product development; Project scheduling; Resource allocation; Simulated annealing; Genetic algorithms

1. Introduction

Product development is the competitive advantage for many industries. To maintain market shares, industries need to effectively manage their product development projects and bring their products to market as early as possible. In today's changing marketplace, accurate project planning and scheduling for product development becomes difficult. Unexpected events (e.g., engineering changes, delays of certain activities, etc.) frequently occur during the product development. It is important for an R&D organization to quickly recognize the impact of unexpected events and effectively reschedule the affected project activities.

Moreover, in today's globalized and highly competitive market, it has become more important for a firm to meet the due date requirement for a product development project than to satisfy the available resource capacity, since a late project will incur a great sales loss and a large amount of penalty to customers. Especially for a development project contracted from a world-class company, a small firm usually does not have

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enough power for bargaining the project due date. However, the unavailable resource capacity can be resolved by working overtime, outsourcing, sharing resources with other projects, hiring more manpower or purchasing additional equipment. In this situation, it is important to have a scheduling decision making tool to assist project managers in repairing the disrupted project schedule with the "hard" due date constraint.

Scheduling of a product development project can be viewed as a resource-constrained project scheduling problem (RCPSP), which has been investigated extensively in the literature (Özdamar and Ulusoy, 1995; Kolisch and Padman, 1997; Brucker et al., 1999). Since the resource-constrained project scheduling problem is NP-complete, optimization approaches are not suitable to solve practical-size problems. Therefore, heuristic approaches have been developed to construct a schedule effectively for practical use. In addition, in recent years, several studies have proposed the meta-heuristic approaches (Glover, 1986) for solving the RCPSP (Lee and Kim, 1996; Mori and Tseng, 1997; Cheng and Gen, 1998; Özdamar, 1999). Most of the research in RCPSP is concentrated on constructive methods to find an optimal or satisfactory schedule. Although extensive research has been done on the rescheduling problem in the manufacturing domain (Smith et al., 1990; Abumaizar and Svestka, 1997), little research has been performed on the dynamic aspect of RCPSP (Sathi et al., 1986; Zweben et al., 1993; Yan et al., 2002).

There has been little research focus on scheduling of the product development project. With the advent of concurrent engineering (Winner et al., 1988), and Belhe and Kusiak (1995) developed a dynamic scheduling heuristic to minimize weighted lateness of design projects. Luh et al. (1999) developed a stochastic programming approach to schedule the design projects with uncertain number of iterations with the goal to minimize project tardiness. Hapke and Slowinski (1994, 1996) represented uncertain activity duration by fuzzy sets and applied dispatching rules to determine the schedules with the minimum fuzzy makespan for software development projects. Wang (2002, 2004) developed fuzzy project scheduling approaches for product development projects with uncertain activity duration and the preferred due date constraint to minimize the possibility of the project being late.

This research models the scheduling of the product development projects as a dynamic constraint satisfaction problem (Dechter and Dechter, 1988), where the project due date is considered as a "hard" constraint that cannot be violated. All unexpected changes during the product development are considered as additions or deletions of constraints to the problem that may lead to constraint violations for the current schedule. This paper proposes meta-heuristic approaches including simulated annealing (Eglese, 1990) and genetic algorithms (Goldberg, 1989) to repair the disrupted schedule with the minimum cost of resource constraint violation. This will enable an R&D organization to recognize the impacts of unexpected events quickly and to reallocate the scarce resources among project activities efficiently.

The paper is organized as follows. Section 2 formulates the reactive project scheduling problem as a dynamic constraint satisfaction problem. The meta-heuristic approaches for scheduling repair are presented in Section 3. The computational experiments are performed in Section 4. Finally, Section 5 concludes this paper.

2. Modeling the reactive project scheduling problem as dynamic constraint satisfaction problem

Due to unexpected events frequently occurring during the product development, the original schedule produced in the project planning stage is often disrupted and has to be adjusted to reflect the actual project status. Therefore, the project scheduling problem for product development is actually a reactive scheduling problem.

This research considers the product development project scheduling problem as a dynamic constraint satisfaction problem (Dechter and Dechter, 1988) that provides a flexible framework to detect and repair schedule conflicts. A constraint satisfaction problem (CSP) (Brailsford et al., 1999) is defined by means of a set $V = \{v_1, v_2, \ldots, v_p\}$ of variables, a domain D_i specified for each variable v_i the values to which it may be assigned, and a set $C = \{c_1, c_2, \ldots, c_w\}$ of constraints on variables, where $c_j : D_1 \times \ldots \times D_p \rightarrow \{true, false\}$,