An Educational Tool for the Resource-Constrained Project Scheduling Problem

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Abstract

The well-known resource-constrained project scheduling problem (RCPSP) involves the determination of a baseline schedule of the project activities that satisfies the finish-start precedence relations and the renewable resource constraints under the objective of minimizing the project duration. We have developed an educational tool that visualizes (amongst others) project networks, baseline schedules, resource profiles and Gantt charts. The tool also features a number of known scheduling algorithms for solving the RCPSP, including an exact branch-and-bound procedure. Project networks can either be read in from files or be built up from scratch, using an intuitive graphical user interface.

1 The basic RCPSP

The basic RCPSP [4] involves a project network $G(N, A)$ with a set N of $n+1$ nodes representing the project activities. We assume a dummy start activity 0 and a dummy end activity n, which denote the start and the finish of the project, respectively. Both dummies have a duration equal to zero and do not consume any resources. The activities in the network are subject to zero-lag finish-start precedence constraints $(i, j) \in A$, indicated by the arcs of the network. We assume the presence of m renewable resource types, with a per period availability a_k, $k \in K$ with $K = \{1, \ldots, m\}$. The project activities i require an integer per period amount r_{ik} of resource type k, $k \in K$. A solution to the RCPSP consists of a vector of start times s_i, $i \in N$ such that the resource and precedence constraints are satisfied, and the project makespan s_n is minimized.

Feasible schedules for the RCPSP can easily be obtained by a so-called schedule generation scheme [7, 1], using an activity list – usually ordered according to a certain priority rule – as input. Numerous procedures have been developed for solving the RCPSP, both heuristic and optimal. The most successful exact procedure for the RCPSP appears to be dedicated branch-and-bound [2, 3].

2 An educational tool

An educational tool for visualizing the RCPSP has been developed in C++. It has a window-based Graphical User Interface (GUI) and runs on all Win32® platforms. The software is capable of handling projects consisting of any number of activities and any number of resource types. Project files in the "rcp" format (this is the format used in the well-known project scheduling library PSPLIB [8]) can be read in. Alternatively, the user can build up a project network from scratch, starting with an empty project and adding activities and precedence relations one at the time. These networks can then be exported to a file in the aforementioned "rcp" format. Early and late start schedules can be calculated, and the slack values of different activities can be graphically displayed under the form of a Gantt chart. The software also supports the calculation of various project statistics, such as resource strength, order strength and coefficient of network complexity, to name a few. A screenshot of the software is presented in Figure 1.

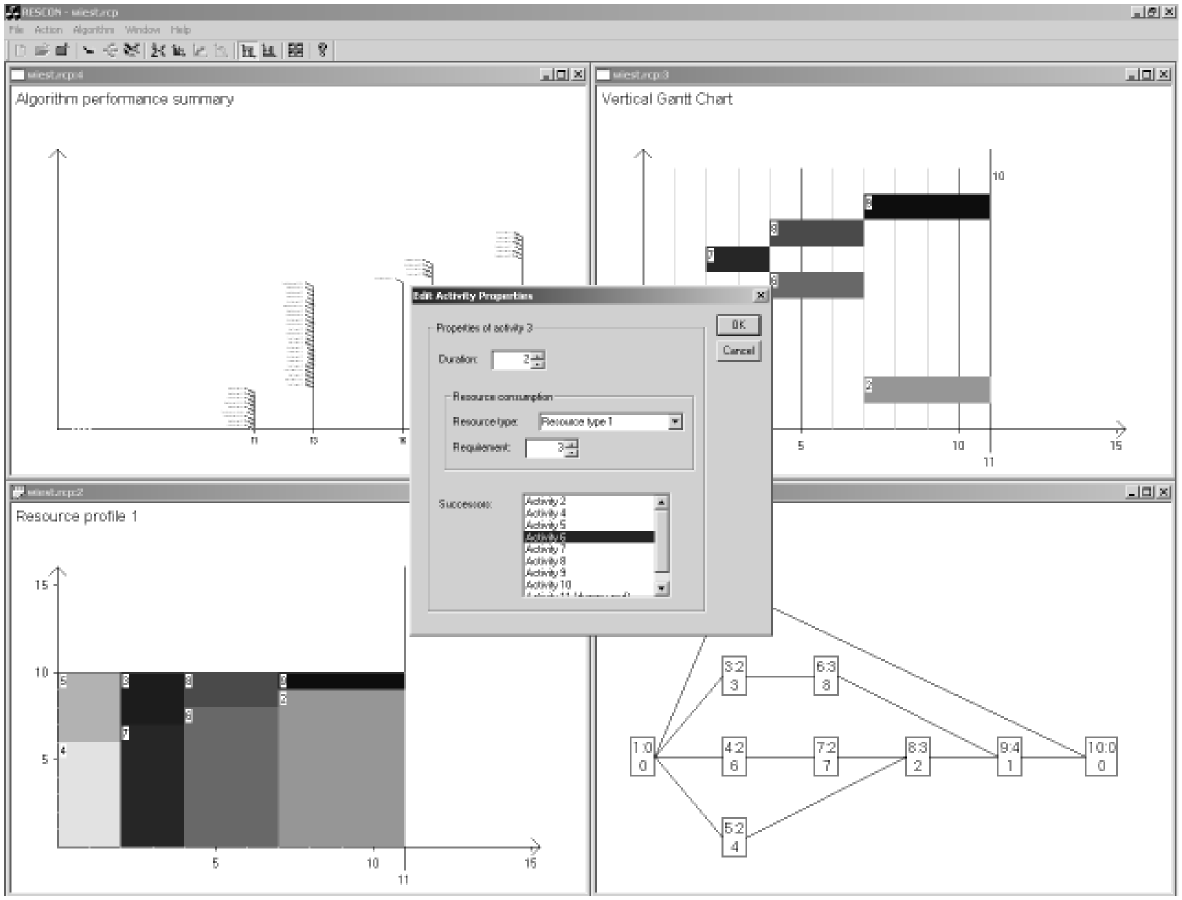

Figure 1: Screenshot of the software

Feasible schedules can be calculated using a large number of constructive heuristics. The software supports both the serial and the parallel schedule generation scheme, in combination with forward, backward or bidirectional planning. The user can choose from eight popular priority lists (e.g. latest finish time, minimum slack, ...), yielding a total of 48 heuristics to calculate a feasible schedule. We have also implemented an exact procedure for solving the RCPSP. It is a branch-and-bound procedure based on the procedure by Demeulemeester and Herroelen (1992), yielding optimal solutions in a relatively short computation time (provided the number of activities is limited). The software provides the possibility of summarizing the results (i.e., the obtained makespan) of the 48 heuristics plus the optimal procedure graphically, on a single timeline.

Also, for educational purposes, we provide the opportunity for "what-if" analysis: project parameters (such as activity durations, resource availability, precedence constraints) can be changed and the schedule can be recalculated, such that the immediate effects on the baseline schedule are just one click away.

As the software is still under development, no version of the software has been made publicly available yet. Because now, the user only has the opportunity to choose between rather poor heuristics on the one hand (the list scheduling procedures), and an optimal but computationally demanding branch-and-bound procedure on the other hand, we plan to incorporate a Tabu Search procedure [5, 6] in the software to solve the RCPSP in a heuristic way, in an attempt to strike a balance between computation time and solution quality.

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