Evolutionary algorithm in multiple-criteria project portfolio scheduling problem

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Keywords : project scheduling, evolutionary algorithms, multiple criteria optimization

1 Introduction

There are many methods for project scheduling. Those methods deliver schedules with optimal project finish time. In real-life applications the schedule should optimize not only project finish time but also resources usage and cash flows. So far, few papers considered the problem of multiple criteria project scheduling problem. Fewer consider the multiple criteria project portfolio scheduling problem. An example of describing and solving the multiple criteria project scheduling problem is presented in the paper written by Viana and de Sousa[4]. They considered resource constrained problem, in which project completion time is minimized, project delay is minimized and disorders in resource usage are minimized as objectives. Problem was solved with PSA and MOTS algorithms. Another example is described in the paper prepared by Leu and Yang[2], who considered resource constrained problem with time, cost and resource usage optimization using genetic algorithm. Hapke, Jaszkiewicz and Słowiński[1] described a problem with three criteria: project cost minimization, project delay minimization, and resource usage optimization. Problem was solved with PSA and MOTS algorithms. Multiple criteria project portfolio scheduling problem was described by Lova, Maroto and Tormos[3]. They proposed the paper in which the problem is solved in two stages. In the first one a time optimal schedule is prepared. In the second stage, the obtained schedule is improved in terms of resources usage. They used priority rule based heuristic.

The purpose of this paper is to present project portfolio scheduling problem as a multiple criteria decision making problem and to solve this problem using evolutionary algorithm. An elitist evolutionary algorithm will be used to solve this problem. Computations will be made on a real-life case study and results will be compared with solution obtained by algorithm used by company on the daily basis.

2 Problem statement

There is a portfolio of projects that needs to be scheduled. By scheduling we will understand setting start and finish time of each activity. There are resources (requirements and availability), cash flows generated by each activity and precedence relationships defined. Project team consists of several members. Moreover, project manager can hire additional members from outside of the team. Those resources are extra paid (and will be called as external resources). Each activity is described by parameters: duration, resources requirements, generated cash flows. A schedule should be a compromise solution between the following criteria: a sum of the penalties for projects in the portfolio delays minimization (delay due to time defined by the decision maker); resource usage optimization by minimization additional cost of using additional resources (resources from the outside of a project team); net cash flows (NPV) maximization.

The following assumptions are taken into consideration: there is a set of $p=1,\dots,P$ projects; each project contains $j=1,\dots,J$ activities; all precedence relationships types are possible; one project realization can depends on the other; started activities cannot be spitted; deterministic time is considered; only renewable resources are taken into account ($k=1,\dots,K$); there are two types of resources: internal (available in the portfolio) and external (available in the company, extra paid);

renewable resources are constrained in each period of time; availability of resources can be different in each period of time.

Mathematical model has the following structure: binary variables: $x_{jpt}=\{0,1\}$; $x_{jpt}=1$ when an activity j of project p last in time t; a sum of the penalties for projects in the portfolio delays minimization: $\sum^{P}[[\max\{\max\{F_p - LF_p, 0\} - Y_p, 0\}] \cdot Z_p] \to \min$; minimization of cost of using additional resources: $\sum^{T}[\sum^{K}[\max\{\sum^{P}\sum^{J}(r_{jpk} \cdot x_{jpt}) - R^{w}_{kt}, 0\} \cdot V_k]] \to \min$; NPV maximization $\sum^{P}\sum^{J} cf_{jp} \cdot e^{-\alpha F_{jp}} \to \max$; a single activity needs to be finished only once: $\bigwedge_{p=1}\bigwedge_{j=1,\dots,J}\sum^{T} x_{jpt} = d_{jp}$; activity finish time: $F_{jp} = \max_{t=1,..,T}(t \cdot x_{jpt})$; activity start time; $\bigwedge_{x_{jpt} \neq 0} S_{jp} = \min_{t=1,..,T}(t \cdot x_{jpt}) - 1$; single activity cannot be disturbed: $F_{jp} = S_{jp} + d_{jp}$; all precedence relationship types are possible: $S_{jp} \geq F_{ip}$; $S_{jp} \geq S_{ip}$; $F_{jp} \geq S_{ip}$; $F_{jp} \geq F_{ip}$; available resources are limited: $\bigwedge_{k=1,\dots,K}\bigwedge_{t=1,\dots,T}\sum_{p=1}^{P}\sum_{j=1}^{J}(r_{jpk} \cdot x_{jpt}) \leq R^{w}_{kt} + R^{z}_{kt}$.

3 Evolutionary algorithm for problem solving

To identify the sample of non-dominated set the SPEA 2[5] (Strength Pareto Evolutionary Approach 2) algorithm is used.

The binary variables are used in the problem described in the section 2, so an individual is a binary matrix, in which the number of rows is equal the JxP and represents activities and number of columns is equal T and represents time units.

A crossover is a process of exchanging random rows between two individuals. Mutation is delaying of a random chosen activity. To deal with constraints a penalty for not feasible is used. If solutions is not feasible its performance function is worsen by multiplying by 2, in case of minimization criterion and multiplied by -1 when criterion is maximization.

4 Conclusion

The company uses a simple priority rule technique. Activities are put to the schedule in the order to the activities lists in the first possible time (time when precedence relationship constraint is meet and when resources are available). Solutions obtained by this technique were dominated by solutions obtained by using SPEA2 algorithm.

The result of the SPEA2 algorithm is an external set with non-dominated solutions. The number of those solutions can be huge. What is a disadvantages in real-life application, when decision maker expects final solution (one solution). This is the reason, why hybrid algorithms (Evolutionary algorithms with local search) should be considered in the future in this kind of problems.

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