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Athanasios Migdalas

Athanasia Karakitsiou

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A Genetic Algorithm for Scheduling Alternative Tasks Subject to Technical Failure

Dalila B.M.M. Fontes and Jos Fernando Gon alves

Abstract Nowadays, organizations are often faced with the development of complex and innovative projects. This type of projects often involves performing tasks which are subject to failure. Thus, in many such projects several possible alternative actions are considered and performed simultaneously. Each alternative is characterized by cost, duration, and probability of technical success. The cost of each alternative is paid at the beginning of the alternative and the project payoff is obtained whenever an alternative has been completed successfully. For this problem one wishes to find the optimal schedule, i.e., the starting time of each alternative, such that the expected net present value is maximized. This problem has been recently proposed in Ranjbar (Int Trans Oper Res 20(2):251–266, 2013), where a branch-and-bound approach is reported. Since the problem is NP-*Hard*, here we propose to solve the problem using genetic algorithms.

Keywords Scheduling under activity failure • Maximization of expected net present value • Biased random-key genetic algorithms

1 Introduction

Companies must plan and optimize their activities in a uncertain environment. The uncertainties may come from several different parts of their business. The uncertainties most commonly addressed in the literature are related to the costs and returns associated with the business. Regarding scheduling problems the most frequently studied uncertainties are resource breakdowns and duration variability. However, other sources of uncertainty exist. For example, Research and Development (R&D) companies, highly dependent on innovation, also face uncertainty regarding the success of their initiatives. These initiatives, usually called projects, may fail. Thus, in order to deal with this kind of uncertainty companies may have

D.B.M.M. Fontes (✉) • J.F. Gon alves
Faculdade de Economia da Universidade do Porto and LIAAD INESC TEC,
Rua Dr. Roberto Frias, 4200-464 Porto, Portugal
e-mail: fontes@fep.up.pt; jfgoncal@fep.up.pt

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to consider several alternative ways of developing their projects (see, e.g., [27, 28]). In this type of projects, the alternatives are of the same kind, although different, and pursue a similar goal. For example, their execution may represent the repetition of trials until success in one is achieved. Usually, the alternatives are related and some alternatives may imply the execution of some other alternatives, i.e., there are precedence relations between some of the alternatives.

This work addresses the scheduling of alternatives subject to technical failure, in order to maximize the expected Net Present Value (NPV) of the project. The NPV of a project is the discounted value of the project cash flows. The NPV is affected by the project schedule and in capital-intensive industries, the timing of expenditures has a major impact on project feasibility and profitability.

Most of the relevant sources of literature considering activity failure come from chemical engineering applications, where Grossmann and his colleagues have been addressing such problems. In [25] a mixed integer linear programming model was proposed to schedule the activities of a single product considering precedence constraints. Activities have associated a cost, a duration, and a probability of success. The objective was to minimize the expected cost. This model was subsequently used on a specific application [26]. In [19] the authors propose a two-stage stochastic optimization approach to account for the uncertainty in the outcome of the trials. A recent survey on optimization challenges and opportunities in the pharmaceutical industry can be found in [21].

Other scheduling problems involving activity failures have been addressed, see the survey in [8]. De Reyck and colleagues study the scheduling of activities with uncertain outcomes, where project success is achieved only if all individual activities succeed. In [7], the authors have considered the project scheduling problem with uncertain activity outcomes and known durations. This work was extended in [4, 5] where activity durations are stochastic. More recently, in [2] the scheduling of projects subject to failure has been considered. In this problem, several projects, each consisting of several activities, have to be scheduled. If an activity of a project fails, the project fails. The authors also consider resource constraints and the possibility of outsourcing. Modular projects, i.e., projects that include the execution of several modules, each of which consisting of several activities, have been considered in [3, 6]. For such a project to be successful every module must succeed. A module succeeds if at least one of its activities succeeds. In the former work, activity durations are deterministic and activities must be performed sequentially, while in the latter, the durations are stochastic and the resources unlimited.

Following on the work of Ranjbar and Morteza [23], we focus on a single firm facing a R&D project or the development of a new product. There are several alternatives of executing the project and its success requires the successful execution of at least one of the available alternatives. Each alternative consists of a single activity and is characterized by a cost, a duration, and a probability of technical success. The successful completion of the project provides a given payoff. These alternatives can be pursued either in parallel or sequentially. The objective is to schedule the activities in such a way as to maximize the expected Net Present Value