Multiobjective Evolutionary Algorithm for Software Project Portfolio Optimization

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ABSTRACT

Large software companies have to plan their project portfolio to maximize potential portfolio return and strategic alignment, while balancing various preferences, and considering limited resources. However, software project portfolios are challenging to describe for optimization in a practical way that allows efficient optimization. In this paper we propose an approach to describe software project portfolios with a set of multiobjective criteria for portfolio managers using the COCOMO II model and introduce a multiobjective evolutionary approach, mPOEMS, to find the Pareto-optimal front efficiently. The proposed approach was evaluated on a set of 50 projects that follow the validated COCOMO II model criteria. Major results are: the proposed project portfolio management approach was found usable and useful; the mPOEMS algorithm shows capabilities for efficiently solving the combinatorial optimization problem of this type.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search—*Heuristic methods*; D.2.9 [**Software Engineering**]: Management

General Terms

Algorithms, Management

Keywords

Evolutionary algorithms, Multiobjective optimization, Project portfolio management

1. INTRODUCTION

Project selection problem (PSP) [1, 6], that constitutes a part of a project portfolio management process, deals with a creation of an optimal mix of projects, out of all potential candidates, which best fit the organisation's needs. Selection of projects is defined by a number of constraints and objective preferences the decision maker considers for the optimization. The complexity of the PSP is based on the often high number of projects from which a subset has to

be chosen, various existent restrictions and a multitude of objective preferences which the optimal portfolio should adhere to. The PSP is NP-hard problem [3] so there is no exact algorithm that solves larger instances of this problem to proven optimality. Hence, heuristic algorithms are an option for finding at least approximate solutions to the optimal ones.

This paper proposes an implementation of an evolutionary-based multiobjective algorithm called mPOEMS [5] for solving the PSP based on general goals which the portfolio management should support. mPOEMS is an iterative optimization algorithm that seeks in each iteration for such a modification of the current solution, called prototype, that improves its quality the best. Modifications are represented as sequences of elementary actions, defined specifically for the problem at hand. mPOEMS uses an evolutionary algorithm to search for the best action sequence that can be considered a structured *hypermutation*.

For the proof-of-concept experiments a test set of fifty IT projects was used. COCOMO II is used to calculate the effort and schedule data of the utilized project pool.

2. FORMAL MODEL

The presented PSP is similar to the knapsack problem in a sense that the goal is to find a subset of projects, from a pool of all potential projects, such that all optimization criteria are optimized and constraints implied by the finite resources are not violated. Additionally, the information assigned to each project not only specifies whether the project is selected, but also specifies when the project starts. The planning horizon of a portfolio is divided into timeframes, the timeframes are in turn divided into smaller units. Here, months are used for the units, and one year for the timeframe. The project start is declared by selecting a month for each project from the available planning horizon.

Following is a list of optimization objectives considered in this work that is based on a thorough investigation of the corresponding literature and discussions with experts in the field of portfolio management:

1. *Potential Revenue* – portfolios with maximal potential overall portfolio return are sought.

2. *Strategic Alignment* – portfolios with maximal alignment of projects to organisation's strategy are sought.

3. *Resource Usage Distribution Metric* – portfolios which have a high resource usage per timeframe, and have the best distribution between the timeframes in the same time are sought.

4. *Risk* – portfolios with maximal deviation of the portfolio risk value from a desired risk range are sought.

5. *Synergy* – portfolios with maximal positive and minimal negative effects among selected projects are sought.

3. PROPOSED MPOEMS APPROACH

This section presents the multiobjective optimization approach based on the Prototype Optimization with Evolved iMprovement Steps (mPOEMS) [5].

3.1 mPOEMS

mPOEMS is a multiobjective extension of the original single objective POEMS algorithm [4]. POEMS is an iterative optimization approach that employs an EA for finding the best modification of the current solution, called *prototype*, in each iteration. Modifications are represented as a sequence of fixed length of primitive actions (mutation operators in standard evolutionary algorithms) defined specifically for the problem at hand. Thus, the modifications can be considered evolved *hypermutations*.

Contrary to POEMS, the mPOEMS maintains a set of the best solutions found so far, called a *solution base* and uses a multiobjective EA (MOEA) based on the dominance concept instead of a simple EA. In each iteration, one solution from the set of non-dominated solutions of the current solution base is chosen as the current prototype, for which the action sequences will be evolved by the MOEA. The best solutions generated by the MOEA as modifications to the prototype are merged with the current solution base. At the end, the set of non-dominated solutions of the final solution base is taken as the result of the run.

3.2 Implementation of mPOEMS for the PSP

In this work, a solution (i.e. the chosen portfolio of projects) is represented by a vector $\overline{x}$ of integers where each position x_i describes whether the project i is selected ($x_i > 0$) or not ($x_i = 0$). Value ($x_i > 0$) specifies in which timeframe the project should start.

For the PSP the following two actions were introduced:

- *changeMonth(projectId, month)* – changes the starting month of a project randomly to another month, with respect to the valid timeframes for the project under consideration.

- *switchOnOff(projectId)* – selects the project to the portfolio if its current status is unselected, and vice versa.

4. RESULTS AND CONCLUSIONS

The test set consists of 50 software projects. The projects are restricted to having 1000 to 37000 source lines of code; the maximum duration of a project is restricted to 18 months; the planning horizon is set to three years (i.e. three timeframes), in each timeframe, the available resources are restricted to 500 person-months; each project has an assigned risk value between 0.2 and 0.8. The well accepted cost estimation framework COCOMO II (Constructive Cost Model)

[2] was used to generate the cost, schedule and effort part of the test set.

We run 20 independent runs with the proposed algorithm. Results presented in this paper show, that mPOEMS is able to generate high quality solutions with respect to the given set of optimization criteria. The progress towards the Pareto-optimal front is well illustrated in terms of the hypervolume metric. The randomly generated starting solution base and the final solution base were covering on average 15.2% (stdev=1.8%) and 76.4% (stdev=0.6%) of the reference objective space volume. This clearly shows the ability of the algorithm to generate solutions close to the Pareto-optimal front.

Most valuable insights are that the complex project portfolio optimization problem with its various constraints and objectives can be solved with the presented approach and that the presented strategy performs highly efficient in regard of the optimization of each of the considered objectives and all of their combinations.

From the practical point of view it is very important and useful that the project portfolio is optimized with respect to all of the optimization criteria simultaneously providing a user with a set of high-quality solutions from which he/she can choose the best one according to his/her posterior priorities in the end.

The full paper can be downloaded at
`http://labe.felk.cvut.cz/~kubalik/PSP_MPOEMS.pdf`

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