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Software project portfolio optimization with advanced multiobjective evolutionary algorithms

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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. Project portfolio managers need methods and tools to find a good solution for complex project portfolios and multiobjective target criteria efficiently. 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. We evaluate the new approach with portfolios choosing from a set of 50 projects that follow the validated COCOMO II model criteria and compare the performance of the mPOEMS approach with state-of-the-art multiobjective optimization evolutionary approaches. Major results are as follows: the portfolio management approach was found usable and useful; the mPOEMS approach outperformed the other approaches.

1. Introduction

Project portfolio management (PPM) is a set of processes used to support a business in conducting the mix of projects, which best fit the organisation's various needs. This set of processes includes the selection of projects an organisation conducts, maintaining the selected projects in portfolios, and periodically reviewing the mix of projects, to check whether the selection still supports the main business goals. Various portfolio processes have already been presented. Most of them do cover the whole life cycle of portfolios, from selecting projects and optimizing portfolios to phase gate review steps [1,16].

Portfolio optimization is a process in PPM that create the best mix of projects, out of all potential candidates. Selection of projects, and optimization of projects can be conducted either manually or automatically. Manual approaches to select projects are for example the Analytic Hierarchy Process (AHP), Q-Sort, scoring models, and portfolio matrices [1]. Commonly used manual approaches are based on some sort of direct comparison and ranking of the alternatives based on project data and individual preferences. Manually conducting the selection of projects is restricted in the number of projects it can deal with, constraints and objective preferences which can be taken care of, as well as the number of objectives the decision makers are able to optimize. This is especially true, since the complexity grows exponentially with the number of available project alternatives [5]. The project selection problem is NP-hard problem [5] thus 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.

The complexity of the project selection problem 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. Common goals of portfolio optimization are maximization of potential revenue and strategic alignment, as well as minimization of negative synergy effects in-between projects selected for a portfolio. Furthermore, portfolios often have to be balanced regarding characteristics of the portfolios. These balancing requirements are found in the number of projects assigned to a specific category, or in the optimization of a portfolio regarding its overall mean risk value.

Manual approaches to this demanding decision problem are restricted in their usefulness for the problem at hand. Promising alternatives to manually selecting projects are found in the field of mathematically based portfolio optimization, and multiobjective optimization. Automated approaches are superior to manual

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approaches in a way that they are able to create a set of efficient portfolios, for which it can be assured that there exist no solutions in the search space which promises better values in at least one of the objectives, and offers at least the same in all the others. This set of efficient solutions is commonly referred to as the Pareto-optimal front. Furthermore, the utilized computational power and sophisticated multiobjective meta-heuristics ensure that the solutions found do have at least the same quality as manually created portfolios. With a high probability, solutions on the Pareto-optimal front found by automated approaches are much better than solutions found with manual approaches. Furthermore, manual approaches will never be able to keep up with the search ability of automated approaches, and the number of considered projects, objectives, restrictions and constraints.

This paper presents the first phase of a decision support framework, which focuses on the selection of projects, using an evolutionary optimization algorithm. An implementation of a nature-inspired optimization framework is presented, using the evolutionary algorithm mPOEMS, based on general goals which the portfolio management should support. This optimization framework is able to find efficient portfolios on or close to the Pareto-optimal front. The second phase, not presented in this paper, comprises a group decision process to efficiently select one portfolio out of the Pareto-optimal front.

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 (simple mutations in standard EAs), defined specifically for the problem at hand. mPOEMS uses an evolutionary algorithm to search for the best action sequence that can be considered an *evolved hypermutation*.

We have chosen mPOEMS since it was recently shown to be suitable for solving discrete multiobjective optimization problems like multiobjective 0/1 knapsack problem [10]. In [10] mPOEMS was shown to produce better or at least competitive results to the state-of-the-art MOEAs such as NSGA-II and SPEA2 on that problem.

The iterative optimization concept based on the evolved hypermutations has proven to be successful approach also for solving hard single-objective combinatorial problems such as the sorting network problem [11], the multiple sequence alignment problem [12] and the shortest common supersequence problem [13].

The presented approach is evaluated on a test set of 50 IT projects. COCOMO II is used to calculate the effort and schedule data of the utilized project pool. The optimization framework claims to consider a very broad range of portfolio optimization characteristics and goals found in the literature. It has been empirically verified that mPOEMS is able to generate high-quality solutions with respect to the given set of optimization objectives. Results of the multiobjective optimization using mPOEMS are compared with results found with the state-of-the-art multiobjective evolutionary NSGA-II and SPEA2.[1] Analyses presented in this paper show, that mPOEMS performs significantly better than NSGA-II and SPEA2 on this problem.

2. Related work

Various approaches have already proven the applicability of mathematically based meta-heuristics for the project selection problem.

In 2000, Ghasemzadeh and Archer [6] presented a decision support system, which follow the process steps of Archer's integrated framework for PPM [1], and combine them with a formal model, considering various variables and constraints. The possibility to making manual adjustments is given through adding or removing projects. A very interesting contribution is the consideration that projects can start in an arbitrary timeframe, given that the project is completed within the planning horizon.

In 2003, Stummer and Heidenberger presented a three-phase approach [19] for PPM in the field of research and development. With the use of an Integer Linear Programming Model, they provided a process to deal with non-numerically restricted project interdependencies, Logical & Strategic constraints as well as Resource & Benefit constraints. One of the main contributions is the examination of resources and project expenditures in their corresponding timeframes. In comparison to the discounting of project attributes to a certain point in time, timeframes deliver a more accurate image of the business environment [19]. Disadvantages of this approach compromise its inability to deal with incomplete data sets, and the process or time-related restriction on approximately 30 projects [19].

In 2004, Doerner et al. published a so-called *Pareto Ant Colony Optimization Approach* [5]. Artificial ants construct valid project portfolios and take into account complex project interactions. The consideration of project synergy, the good results it has shown in experiments and the possibility of easily adding heuristic information to the algorithm makes it a valuable approach [5].

In 2005, Medaglia et al. presented an evolutionary approach for project selection [15]. They utilized a genetic algorithm, combined with random parameter values to model project selection under uncertainty. To model uncertainty is of specific relevance, because it is often difficult in the project selection stage to define parameter values exactly, due to various internal and external influences (risk, political issues, interest rates, economic changes, and so on). Uncertainty could be modelled as specific random values following triangular, exponential, and Erlang distributions like in [15], or with the use of likely values as proposed in [1].

Closely related to the work presented in this paper is the work by Gueorguiev et al. [7], where a software project planning is formulated as bi-objective optimization problem with robustness and project completion time treated as two competing objectives.

Each of the above-presented approaches add valuable information and knowledge to the topic of creating optimized project portfolios. The approaches have been analysed and inspired the authors of this paper in creating an evolutionary-based approach to the project selection problem. Some ideas of these works are used in the presented approach, and expanded with new methods.

The next section presents the list of goals the presented project selection portfolio optimization approach supports. The list of goals is based on a thorough investigation of the corresponding literature and discussions with experts in the field of portfolio management.

3. Portfolio optimization goals

The following listing describes the goals which an optimization approach for the project selection problem should support:

1. Consider and limit the available resources/budget per timeframe.
2. Support "must-select" restrictions.
3. Take synergy effects into account.
4. Take logical relationships into account.
5. Maximize the overall strategic alignment value.
6. Support balancing of risk, project categories and return time.
7. Maximize potential portfolio return.
8. Provide possibility to define project starting timeframes.

Goal Nr. 1 deals with the limited availability of resources in an organisation. A project needs a certain amount of resources across

[1] The PISA framework [22] was used to adapt NSGA-II and SPEA2 to the presented portfolio optimization approach.