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Differential evolution with Pareto tournament for the multi-objective next release problem

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ABSTRACT

Software requirements selection is the engineering process in which the set of new requirements which will be included in the next release of a software product are chosen. This NP-hard problem is an important issue involving several contradictory objectives that have to be tackled by software companies when developing new releases of software packages. Software projects have to stick to a budget, but they also have to cover the highest number of customer requirements. Furthermore, in real instances of the problem, the requirements tackled suffer interactions and other restrictions which complicate the problem. In this paper, we use an adapted multi-objective version of the differential evolution (DE) evolutionary algorithm which has been successfully applied to several real instances of the problem. For doing this, the software requirements selection problem has been formulated as a multiobjective optimization problem with two objectives: the total software development cost and the overall customer's satisfaction, and with three interaction constraints. On the other hand, the original DE algorithm has been adapted to solve real instances of the problem generated from data provided by experts. Numerical experiments with case studies on software requirements selection have been carried out to demonstrate the effectiveness of the multiobjective proposal and the obtained results show that the developed algorithm performs better than other relevant algorithms previously published in the literature under a set of public datasets.

1. Introduction

The complexity and extension of modern software systems have been increased in the last decade. In addition, software products have to be usually developed in limited periods of time and with severe cost restrictions. Thus, software development companies have to efficiently satisfy large sets of requirements by minimizing the production efforts (in time and cost). In fact, in most cases it is not possible to develop all the new features suggested by the clients. Software requirements optimization is an important task in Software Engineering, and especially relevant within the incremental approaches of software development, such as in the agile methodologies [1]. In these methodologies, the software product is developed by generating releases which have to be produced in short iterative cycles. A new set of requirements, tailored to fit the needs of the clients and the development costs is proposed for each iteration. In this context, the challenge of Software Engineering is to define which requirements should be developed taking in consideration several complex factors (priority for different clients with different importance, development effort, cost restrictions, interactions between different requirements, etc). There is not a simple solution to this complex problem, which is also called in the related literature next release problem (NRP) [2].

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The NRP is an NP-hard problem [3] which simultaneously manages two independent and conflicting objectives which have to be simultaneously optimized: the development effort (cost), and the clients' satisfaction. Thus, the problem cannot be managed by traditional exact optimization methods. In this case, multi-objective evolutionary algorithms (MOEAs) are the most appropriate strategies [4,5], because MOEAs tackle simultaneously several conflicting objectives without the artificial adjustments included in classical single-objective optimization methods. However, most of related works in the bibliography are simplified by using an aggregation function and they manage the problem as a single objective version of the problem. Furthermore, there are others works that do not tackle the interactions produced between the requirements in real NRP instances of the problem.

In this paper, a novel technique within the Search-Based Software Engineering (SBSE) [6] research field has been proposed to deal with a real multiobjective version of the NRP (MONRP). Specifically, in this paper we propose a multi-objective approach based on the differential evolution (DE) metaheuristics, which is a population based evolutionary algorithm [7]. We have modified the original scheme of DE to deal with the multiobjective NRP (MONRP). Thus, the MOEA proposed, which was named Differential Evolution with Pareto Tournaments (DEPT) incorporates some multi-objective features, such as the concept of Pareto tournament or the non-dominated sorting [8]. In order to test the accuracy of the proposed algorithm, we have compared it with the multi-objective standard NSGA-II (Fast Non-dominated Sorting Genetic Algorithm) [8], and other approaches proposed in other works published in the literature. As will be shown in this paper, DEPT algorithm provides high quality results, surpassing the results obtained by other authors, for several instances of the software requirements selection problem.

The rest of the paper has been organized as follows: Section 2 discusses related work. Section 3 describes the basic background on the problem and the multiobjective formulation which has been proposed. In Section 4, we explain our proposal and we provide some implementation details about the algorithm developed to deal with the software requirements selection problem. The experiments performed and the results obtained are presented and analyzed in Section 5. Finally, Section 6 summarizes the conclusions of the paper.

2. Related work

Requirements optimization is an NP-hard problem [3] which consists of selecting a set of requirements that will be developed for the next release of a software product, such that the requirements selected minimize the development cost and maximize the clients' satisfaction. The problem evaluates two conflicting objectives, and both objectives have to be equally considered by the solutions found. In the literature, Karlsson proposed in [9] two kinds of methods for selecting and prioritizing software requirements: Analytical Hierarchy Process (AHP) and Quality Function Deployment (QFD). In QFD, requirements are prioritized in an ordinal scale, and in AHP the requirements are classified by a pair cost-value. However, both kinds of methods do not support requirements interdependencies, which are real needs nowadays, and they have to perform a huge number of comparisons when the project scale is increased.

The requirements selection problem was firstly formulated as a single-objective problem in the Search-Based Software Engineering (SBSE) field by Bagnall et al. in [2]. SBSE is the research field in which search-based optimization algorithms are proposed to tackle problems in Software Engineering [6]. The original problem proposed in [2] has been solved with different metaheuristics along the last years. However, most of the approaches published are single-objective evolutionary algorithms which combine the objectives by using an aggregation function [10,11]. In all cases, those works did not consider the interactions produced among the requirements. Moreover, single objective formulation has the inconvenient of making a biased search of the solution space, because the objectives have to be artificially aggregated in some way, for example with a weighted sum of the objectives.

The NRP has been recently formulated as a multi-objective optimization problem (MOOP). Zhang et al. proposed the first multi-objective formulation for the original NRP [12] (MONRP). This formulation tackles each objective separately, without any combination function, and without considering any problem constraint, such as the interactions produced among the requirements or the cost limitations. In [13,14], the authors also use multi-objective optimization for the analysis of trade-offs among multiple clients with potentially conflicting requirements priorities, but the interactions produced among the requirements are not again considered. The same occurs in the works [15–17], in which different multi-objective evolutionary algorithms are proposed for solving NRP, but dependencies among requirements are not considered. In [15], the authors propose a quantum inspired evolutionary algorithm. On the other hand, in [16], the authors propose the well-known algorithms: PAES (Pareto Archived Evolution Strategy) [18], NSGA-II (Fast Non-dominated Sorting Genetic Algorithm) [8], and MOCell (MultiObjective Cellular Genetic Algorithm) [19] for solving the requirements selection problem. Finally, in [17], the authors solve the problem by using an Ant Colony Optimization (ACO) algorithm [20].

As far as we know, the only two studies in which the MONRP is tackled by considering the interactions between the software requirements are the works by Sagrado et al. [21,22], and by Souza et al. [23]. All those works propose the use of different ACO strategies to solve the problem, but only in [22], the datasets used in the study are public, so our results will be compared with that study in Section 5. To this respect, it is worth mentioning that many of the related studies do not make public the information about the datasets used (probably for commercial reasons), so it is not possible to perform numerical comparisons with them.

In this paper, we present a multi-objective search-based approach based on the differential evolution evolutionary algorithm [7]. We have adapted the algorithm to work with a MONRP formulation in which different types of requirements