Size-Constrained Regression Test Case Selection Using Multicriteria Optimization

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Abstract—To ensure that a modified software system has not regressed, one approach is to rerun existing test cases. However, this is a potentially costly task. To mitigate the costs, the testing effort can be optimized by executing only a selected subset of the test cases that are believed to have a better chance of revealing faults. This paper proposes a novel approach for selecting and ordering a predetermined number of test cases from an existing test suite. Our approach forms an Integer Linear Programming problem using two different coverage-based criteria, and uses constraint relaxation to find many close-to-optimal solution points. These points are then combined to obtain a final solution using a voting mechanism. The selected subset of test cases is then prioritized using a greedy algorithm that maximizes minimum coverage in an iterative manner. The proposed approach has been empirically evaluated and the results show significant improvements over existing approaches for some cases and comparable results for the rest. Moreover, our approach provides more consistency compared to existing approaches.

Index Terms—Software regression testing, test case selection, integer programming, Pareto optimality.

1 Introduction

Software systems evolve constantly to provide the required functionalities and to adapt to ever-changing customer needs. However, modifying software can break the previously verified functionalities of the system, causing *regression faults*. Software regression testing is therefore required in order to detect such faults. The dominant strategy is to rerun test cases that are available from an earlier version of the product. However, rerunning the entire test suite in its original form is often too costly [1]. Researchers have therefore sought ways of optimizing the regression test suite to make its execution more cost effective. Two major approaches have emerged from these efforts: Regression Test Selection (RTS) and Regression Test Prioritization (RTP). RTS techniques (e.g., [2], [3], [4], [5], [6], [7], [8], [9], [10], [11]) select a subset of test cases for re-execution, reducing the overall effort. RTP techniques (e.g., [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26]) reorder test cases based on their perceived importance, thereby enabling a faster detection of faults.

Many empirical studies have evaluated existing RTS and RTP techniques based on a variety of programs and process-related assumptions (e.g., [5], [13], [14], [27], [28], [29], [30]). Two observations are common among these studies. First, the relative performance of a technique varies across different programs/processes (e.g., [28], [30]). This observation motivates regression-testing approaches that are more consistent across different programs. Second, the studies show a gap between existing and hypothetical optimal solutions to some instances of the problem (such as RTP) (e.g., [13], [27]), indicating that existing criteria/algorithms are not sufficient. Since the fault revealing phenomenon is a probabilistic process, any single criterion is only an indication of where faults might reside, thereby potentially limiting the fault detection capability. Using more than one criterion can help alleviate this problem (e.g., [11]).

Time constraints on the testing process is an important factor in the cost effectiveness of regression-testing techniques. Recent studies show that cost effectiveness is highest when time constraints enforce the incomplete execution of test suites [28], [29]. It is therefore natural and, as we will argue in this paper, beneficial to include as an input to the process some form of estimation for the available testing time. As we shall see, this paper covers the following points:

- We introduce the Size-constrained Regression Test Selection (SRTS) problem, which is to select a subset of the test suite with a given number of test cases.
- We demonstrate, through examples, the benefits of using more than one objective in regression test suite selection and prioritization.
- We introduce a new criterion for regression test suite selection and prioritization: maximizing the minimum sum of coverage (*max-min* criterion) across all software elements.[1]
- We formulate an Integer Linear Programming[2] (IP) problem that combines the max-min criterion and a second criterion of sum of coverage as two distinct optimization criteria.

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1. In this paper, software elements refer to any structures of code for which a measure of test coverage can be defined. Examples are classes, methods, and basic blocks.
2. In this paper, we use the “Integer Programming” term and its abbreviation “IP” to refer to Integer Linear Programming.