Poster: Grafter: Transplantation and Differential Testing for Clones

Tianyi Zhang, Miryung Kim
University of California, Los Angeles
{tianyi.zhang,miryung}@cs.ucla.edu

ABSTRACT

Code clones are common in software. When applying similar edits to clones, developers often find it difficult to examine the runtime behavior of clones. The problem is exacerbated when some clones are tested, while their counterparts are not. To reuse tests for similar but not identical clones, **GRAFTER** transplants one clone to its counterpart by (1) identifying variations in identifier names, types, and method call targets, (2) resolving compilation errors caused by such variations through code transformation, and (3) inserting stub code to transfer input data and intermediate output values for examination. To help developers examine behavioral differences between clones, **GRAFTER** supports fine-grained differential testing at both the test outcome level and the internal program state level. Our evaluation shows that **GRAFTER** can successfully reuse tests and detect behavioral differences. The tool is available for download at <http://web.cs.ucla.edu/~tianyi.zhang/grafter.html> and the demo video is available at <https://youtu.be/1iqAeuM8s3U>.

KEYWORDS

Code clones, software transplantation, differential testing

1 INTRODUCTION

Code reuse via copying and pasting is a common practice in software development. Prior studies show that up to 25% of code in modern software contains *code clones*—code similar to other code fragments elsewhere. Manually adapting clones is error-prone. Therefore, developers often rely on regression testing to check for inconsistent or missing edits on clones [7]. However, a lack of tests exacerbates such situation, where some clones are tested while their counterparts are not. In fact, our study shows that, in 46% of studied clone pairs, only one clone is tested by existing tests, but not its counterpart [6]. No existing techniques can help programmers reason about runtime behavior differences of clones, especially when clones are not identical and when clones are not tested. In the absence of test cases, developers can only resort to static analysis techniques to examine clones [3, 7], but these techniques are limited to finding only pre-defined types of cloning bugs such as renaming mistakes or control-flow and data-flow inconsistencies.

This paper describes a clone transplantation and differential testing technique called **GRAFTER**, based on our ICSE 2017 paper [6].

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Given a clone pair and an existing test suite, **GRAFTER** contrasts the runtime behavior of clones using the same test. Test reuse for clones is challenging because clones may appear in the middle of a method without a well-defined interface (i.e., explicit input arguments and return type), which also makes it hard to directly adapt test for reuse. **GRAFTER** identifies input and output parameters of a clone to expose its de-facto interface and then grafts one clone in place of its counterpart to exercise the grafted clone using the same test. **GRAFTER** tracks the test status (e.g., pass or fail) as well as program states during the test so that a user can compare these values to examine the behavioral difference between clones.

2 APPROACH AND TOOL SUPPORT

Similar to how organ transplantation may bring incompatibility issues between a donor and its recipient, a grafted clone may not fit the context of the target program due to variations in clone content. **GRAFTER** takes four steps to ensure the type safety of clone transplantation.

Variation identification. **GRAFTER** first performs inter-procedural analysis to identify the input and output parameters as well as method calls referenced by each clone and its subroutines. **GRAFTER** then matches the input and output parameters and method calls between clones and detects the parameters and method calls that are defined in one clone but not in the counterpart clone.

Code transplantation. To resolve compilation errors caused by clone variations, **GRAFTER** applies five transplantation rules to handle variable name variation, method call variation, variable type variation, expression type variation, and recursion.

Data propagation. Similar to how surgeons reattach blood vessels to ensure the blood in the recipient flows correctly to the vessels of the transplanted organ, **GRAFTER** also needs to make sure the input data flows correctly into the grafted clone and the output data flows back to the same assertion check of the original test. Therefore, **GRAFTER** inserts stub code to ensure that (1) newly declared variables consume the same input data as their counterparts in the recipient and (2) the updated values flow back to the same test oracle.

Figure 1 shows a grafted clone with stub code generated by **GRAFTER** for data propagation. Lines 307–311 are stub code to propagate the input data from `excludes` and `excludeList` to the corresponding variables, `includes` and `includeList`, in the grafted clone. Lines 313–314 and 323–324 are stub code to propagate the updated value from the affected variable `includeList` back to `excludeList` at the two exits of the grafted clone.

Differential testing. **GRAFTER** supports behavior comparison at two levels. The test-level comparison runs the same test on two clones and compares the test outcomes. The state-level comparison compares the intermediate program states for affected variables at the exit(s) of the clones. **GRAFTER** instruments code clones to

The most related test reuse technique is Skipper. Skipper copies associated portions of a test suite when developers reuse code [4]. It determines relevant test cases and transforms them to fit the target system. Skipper is built on Gilligan [2] and requires users to provide a *pragmatic reuse plan* to establish the mapping of reused entities (e.g., classes, methods) from the original system to the target system. Skipper assumes that clones are full-feature clones at the level of

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³<http://mutation-testing.org/>