**Emerging Topics in Software Engineering**

**UFCFCD-15-M**

**Student Number: 15027313**

**A Critical Review of Utilising Search-Based Software Engineering Techniques to Refactor Code**

**Word Count:**

# Introduction

Search-based software engineering (SBSE) is the name given to the search-based optimisation subfield of software engineering. It involves using metaheuristic search techniques to find a near-optimal solution, and will result in a decent solution but cannot guarantee that it is the very best solution. Henceforth, search-based refactoring will be referred to as SBR.

There are several ways to apply this to a variety of issues, but this review will focus on search-based or sear-supported refactoring. Refactoring is the activity of improving the internal structure of code, while leaving the external structure unchanged. Search-based refactoring is about automatically discovering and performing useful refactorings, which has previously been a predominantly manual activity due to the difficulties of successfully locating and accomplishing this automatically.

“Software systems are subject to continual change and as they evolve to reflect new requirements, their internal structure tends to degrade. The cumulative effect of such changes can lead to systems that are unreliable, difficult to reason about, and unreceptive to further change.” (Harman and Tratt, 2007).

The scope of this topic will include the use of SBSE to locate possible areas of, as well as performing, refactoring of existing code bases.

“The process of writing code can be compared to that of writing a paper or any other document – it starts with some ideas, a few drafts, and then a lot of time spent on refining and rewording, and is not something that should be rushed. Quality code takes a lot of time to write, and just like the writing of draft after draft will increase the author’s understanding of the topic area, code is written, changed, and changed again times and times over as the developers’ understanding of the system and the requirements expands. It is in the human nature to start small and build upward; in this case starting with code that works with limited functionality, expanding it to implement more functionality, and then refining it to optimise performance, readability, error handling, and so on.” (Birkehaug, 2016)

<place here some background and brief history. What is the scope and context of your chosen emerging topic?>

# Focus of critical review

Harmon and Langdon from UCL are two widely published and cited researchers in the area.

< What are the main areas of your chosen emerging topic? Who are the key researchers in the community of your emerging topic? In your critical review, what is/are the research question/s posed? >

# Survey methodology

The principal method behind locating papers was through the use of Google Scholar. The reason for choosing this particular search engine is that they display articles from a variety of different sources, and is a quick way to get an overview of papers as well as an indication of their recognition in the field, as they include a count of citations for each publication. While the citation count may indicate popularity and high-quality research, it should also be noted that these may be very low for newer publications, and it is thus difficult to judge how well a paper is received by these alone.

The first search done was “search based refactoring”, and did not include patents or citations. A brief skim of the abstract for the first 50 hits deemed the majority generally relevant, so as this essay aims to cover state of art, the search was narrowed down to only include articles published since 2012, resulting in a publication range of approximately 4.5 years at the time of writing. The software engineering field moves very quickly and this range appeared to provide enough relevant publications to fulfil this work’s requirements.

The following list shows search hit number, titles and publication years of the first 20 hits, sorted by publication dates in descending order. The ones marked with an asterix are the ones that had full-text available and the titles in bold are those that were ultimately included in the review, with justifications to follow.

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| --- | --- | --- |
| # ft | Title | Year |
| 11 \* | **An experimental search-based approach to cohesion metric evaluation** | **2016** |
| 14 | [Book] Search-Based Software Engineering: 7th International Symposium, SSBSE 2015, Bergamo, Italy, September 5-7, 2015, Proceedings | 2015 |
| 20 | AutoRefactoring | 2015 |
| 10 \* | **On the use of many quality attributes for software refactoring: a many-objective search-based software engineering approach** | **2015** |
| 8 \* | **Search-based refactoring: Metrics are not enough** | **2015** |
| 1 \* | **Automated migration of build scripts using dynamic analysis and search-based refactoring** | **2014** |
| 3 \* | **High dimensional search-based software engineering: finding tradeoffs among 15 objectives for automating software refactoring using NSGA-III** | **2014** |
| 12 | On the use of machine learning and search-based software engineering for Ill-defined fitness function: a case study on software refactoring | 2014 |
| 13 \* | Search based software engineering for software product line engineering: a survey and directions for future work | 2014 |
| 18 \* | **[Keynote] Dynamic adaptive Search Based Software Engineering needs fast approximate metrics** | **2013** |
| 17 \* | Pareto-optimal search-based software engineering (POSBSE): A literature survey | 2013 |
| 7 \* | **Search-based refactoring detection** | **2013** |
| 9 | Search-based refactoring detection using software metrics variation | 2013 |
| 2 \* | **Search-based refactoring using recorded code changes** | **2013** |
| 16 \* | Dynamic adaptive search based software engineering | 2012 |
| 15 | Improving software security using search-based refactoring | 2012 |
| 4 | Search based software engineering: Techniques, taxonomy, tutorial | 2012 |
| 19 \* | Search-based model transformation by example | 2012 |
| 6 \* | **Search-based refactoring: Towards semantics preservation** | **2012** |
| 5 \* | **Search-based software engineering: Trends, techniques and applications** | **2012** |

Based on the titles as well as the abstracts provided by Google Scholar, most of these 20 articles were seemingly relevant in the sense that they refer to search-based refactoring, and include one of the SBSE techniques in some way. A closer look did however reveal that this was not the case for all of them. Several excluded papers turned out to reference other potentially relevant papers, some of which were found in the search, but those that were not have not been included as a sufficient amount of papers passed the selection criteria.

* #4 (Harman *et al.,* 2012) was excluded, as it is a tutorial in the shape of a book chapter and not a research paper.
* #13 (Harman *et al.,* 2014) was also deemed irrelevant as it focuses on SBSE for software product lines, and only mentions refactoring in a generic listing of the possible applications of SBSE.
* #14 (de Oliveira Barros and Labiche, 2015) is also a reference to book and not an individual paper, and has been excluded.
* #16 (Harman, *Burke et al.,* 2012) is predominantly about dynamically adaptive software and not refactoring in the sense of only changing internal structure (as well as only mentioning refactoring a single time), and has been excluded too.
* #17 is a literature survey of papers using multi-objective search to find solutions, and only mentions refactoring in the titles of one of the surveyed works, which being published in 2007 also falls out of scope of this review.
* #19 does mention a plan of adapting their approach to other transformation problems including refactoring, but does not currently do so and has been excluded.
* #12, 15 and 20 were not available in full-text.

Following is a short summary of the ten papers that passed the selection and were available in full-text through a university account, as well as one (#8) that could fortunately be obtained directly from one of the authors.

1. “Automated migration of build scripts using dynamic analysis and search-based refactoring” (Gligoric *et al*., 2014), is using SBR to raise the abstraction level of the code, in order to assist the process of migrating build scripts.
2. “Search-based Refactoring Using Recorded Code Changes” (Ouni, Kessentini and Sahraoui, 2013) is using code changes recorded over time together with structural and semantic information in order to come up with more precise and efficient refactoring suggestions.
3. “High dimensional search-based software engineering: finding tradeoffs among 15 objectives for automating software refactoring using NSGA-III” (Mkaouer *et al*., 2014) proposes a scalable SBSE approach based on an evolutionary optimization method where the refactoring solutions are evaluated using 15 different quality metrics.
4. “Search-based software engineering: Trends, techniques and applications” (Harman, Mansouri and Zhang*,* 2012) provides a review and classification of SBSE literature, highlighting areas in need of more research.
5. “Search-based refactoring: Towards semantics preservation” (Ouni *et al*., 2012) focuses on finding an optimal refactoring sequence in order to minimise semantic errors while maximising quality improvements.
6. “Search-based refactoring detection” (Mahouachi, Kessentini and Cinnéide, 2013b) uses global and local heuristic search algorithms together with the code’s structural information to automate the detection of source code refactorings, using a manually revised version as a benchmark for the automatic refactoring, aiming to keep their metrics similar.
7. “Search-based refactoring: Metrics are not enough” (Simons *et al.,* 2015) recommends that future SBSE refactoring research should keep the human-in-the-loop in order to refactor code in a way that is helpful to the software engineers.
8. “On the use of many quality attributes for software refactoring: a many-objective search-based software engineering approach” (Boukdhir *et al.,* 2014) tackles the problem of optimising conflicting objectives by introducing a many-objective refactoring technique, evaluating refactoring solutions with a set of 8 distinct objectives.
9. “An experimental search-based approach to cohesion metric evaluation” (Cinnéide *et al.*, 2016) propose a search-based refactoring technique used to ‘animate’ metrics and observe their behaviour in a practical setting, in order to compare and discover how metrics relate to each other.
10. “Dynamic adaptive Search Based Software Engineering needs fast approximate metrics” (Harman, Clark and Cinneidez, 2013) discuss using metrics as fitness functions in order to search for sequences of refactorings and evaluate their effect on various metrics, with the goal of identifying metric relationships.

# Search-based refactoring

Harman, Mansouri and Zhang’s literature review (2012) identified that SBSE had been applied to refactoring, and that current research had addressed their refactoring question “What is the best sequence of refactoring steps to apply to this system?” Their work acknowledged there had been developments in the field resulting in several various approaches to using SBSE to automate refactoring, and that the SBR work they reviewed could be partitioned into two groups based on two main goals, as well as whether the approach was single or multi-objective. The first goal was to optimise the program; the second was to optimise the applied sequence of refactoring steps. It appears that these two goals are still some of the main objectives of SBR at the time of writing.

Falling under the second goal, Gligoric *et al.* (2014) used SBR to explore various sequences of refactorings to identify the shortest possible build script, and improved the runtime of the SBR by using the partial-order reduction technique, reducing the search space by applying a model-checking algorithm.

Ouni, Kessentini and Sahraoui (2013) also focused on optimising the refactoring suggestions. Their solution was to use a multi-objective optimisation approach in order to improve code quality. By using records of previous code changes as well as structural and semantic information, they used a search-based approach to improve the efficiency of new refactoring suggestions.

# The human aspect

Some of the papers identified in this work do indeed fall into the categories identified by Harman, Mansouri and Zhang (2012), but recent developments see the need of more categories in order to partition current state of art. For example, Simons *et al.* (2015) encouraged researchers to study ways to keep the human-in-the-loop for future SBR work, which may by some be perceived as backtracking in a field that is concerned with automating tasks that previously have been primarily human-centric.

Although, one must keep in mind that writing code is still at a stage where the human is incredibly important and required to both understand and maintain the code base. Discovering a way of bringing the software engineers back into the loop in an ordinarily increasingly automated task, to make decisions based on personal opinions, may ultimately result in solutions that more beneficial at this stage. Should the creation of software ever become a completely or primarily automated task it may be advantageous to exclude the human aspect, but for now, they are (arguably) necessary. If this paper is to be categorised by goal like in the aforementioned review, the goal could fall under tailoring refactoring output to engineer preferences. While some may say that this falls under the goal of optimising the program, publications on using SBR to optimise a program are generally concerned with performance metrics and not the subjective opinions of the developers, meaning that Simons *et al.* (2015) are part of raising some important, fairly uncharted and issues.

***N* <place the title of AREA *N* here>**

<place your critical review of theme *N* here>

***N*+1 CONCLUSIONS AN FUTURE DIRECTIONS**

<place your conclusions and suggestions for future directions here>

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