Department of Computer Science,
University of Saskatchewan

July 10, 2020

**The Guest Editors**
Journal of Systems and Software

Re: Submitting an extended version of our earlier work

**Dear Guest Editors**,
We would like to submit an extended version of our earlier work on combining clone analysis with evolutionary coupling for change impact analysis. Our earlier work titled as "Associating Code Clones with Association Rules for Change Impact Analysis" was published in SANER (International Conference on Software Analysis Evolution and Re-engineering) 2020. In this work we showed that consideration of clone analysis can significantly improve the co-change suggestion accuracy of an evolutionary coupling based technique called Tarmaq. For clone analysis, we used the NiCad clone detector. We answered five research questions in our previous work in order to establish the importance of considering clone analysis for suggesting co-change candidates. We extend our previous work by answering four additional research questions (RQ 6 to RQ 9) with a goal of refining the co-change suggestions obtained by analyzing code clones. We show that Tarmaq performs significantly better in suggesting co-change candidates in combination with the refined suggestions from NiCad results than with the unrefined suggestions. In the following paragraphs, we describe how we extend our earlier work.

- **Investigation towards realizing the importance of refining clone-based co-change suggestions.** In our new research question RQ 6, we analyze whether it is important to refine the clone-based co-change suggestions before combining those with the suggestions from Tarmaq. Our investigation and findings from RQ 6 establish the necessity of refining the suggestions obtained by analyzing code clones. Table VI and Fig. 11 are the newly added table and figure for answering RQ 6. Our newly added section, Section VI.F, contains the details of RQ 6.

- **Investigating how we can refine the clone-based co-change suggestions.** We have added two research questions, RQ 7 and RQ 8, in order to investigate the nature of true positive and false positive co-change suggestions from NiCad results. In RQ 7, we investigate whether proximity of the clone-based suggestions from their target methods has any impact on their possibilities of being true positives. In RQ 8, we investigate whether a clone-based true positive co-change candidate and its target method have a high possibility of being created together in the same revision. We obtain promising results from our investigations regarding RQ 7 and RQ 8. Table VII, Table VIII, Fig. 12, Fig. 13, Fig. 14, and Fig. 15 are the newly added tables and figures for answering RQ 7 and RQ 8. Our newly added section, Section VI.G and Section VI.H, contain the details of RQ 7 and RQ 8.

- **Investigating whether our suggested refining steps can really improve co-change suggestion accuracy.** In RQ 9, we investigate whether our findings from RQ 7 and RQ 8 can be utilized for refining the clone-based co-change suggestions as well as for improving the suggestion making accuracy of the technique that combines Tarmaq and NiCad. According to our investigation, our findings from RQ 7 and RQ 8 can be reasonably applied on NiCad-based co-change suggestions to refine such suggestions. Tarmaq performs significantly better when combined with the refined suggestions from NiCad than with unrefined suggestions. Our newly added section, Section VI.I, contains the details of RQ 9.

- **Updating different sections in the paper to incorporate our new findings.** We have updated different sections such as abstract, introduction, related work, and conclusion by adding our new findings from our extended research.

We believe that our extended version contains at least 60% more content than our earlier work.

Sincerely,

Manishankar Mondal
Banani Roy,
Chanchal K. Roy, and
Kevin A. Schneider