【Grant-in-Aid for Scientific Research (S)】
Integrated Disciplines (Informatics)

Title of Project : Refinement and Extension of Higher-Order Model Checking

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Research Area : Theoretical Computer Science
Keyword : Program theory, Formal verification

【Purpose and Background of the Research】

As a lot of important infrastructures are nowadays controlled by computers, it is important to guarantee the reliability of computer software. Higher-order model checking, the main subject of this project, is an extension of model checking, which has been considered a promising method for system verification. Higher-order model checking has more potentials than the traditional, finite state model checking.

We have already constructed the first higher-order model checker in the world, and implemented a fully automatic verifier for functional programs on top of it. We have also shown that by compressing data in the form of a program that generates them, we can use higher-order model checking to apply a variety of operations (such as pattern matching) to the compressed data without decompression.

The goal of this project is to significantly extend the previous results on higher-order model checking. We aim to establish more solid theoretical foundations for higher-order model checking, and significantly improve the size and properties of programs that can be automatically verified, and the quality of data compressions and manipulations based on higher-order model checking.

【Research Methods】

We set up the following four sub-topics, and study them in parallel.

(1) Theoretical foundations of higher-order model checking: Higher-order model checking is concerned about properties of the (possibly infinite) tree that is generated by a higher-order tree grammar. We plan to attack important open problems about the higher-order grammars. We also plan to provide a theoretical justification of why many instances of higher-order model checking can be solved in practice, despite the extremely high worst-case complexity of higher-order model checking. Based on these theoretical results, we also plan to develop a more efficient higher-order model checker.

(2) Applications to automated verification of functional programs: We have already constructed an automated program verification tool MoCHi for functional programs. We plan to improve it, so that much larger programs and a wider range of specifications can be handled

(3) Extended higher-order model checking and its applications to verification of object-oriented and concurrent programs: We plan to develop a better extended higher-order model checker, and construct fully-automated verification tools for object-oriented/concurrent programs on top of it.

(4) Applications to data complexity: We plan to improve data compression/manipulation methods based on higher-order model checking. We also plan to investigate their applications to knowledge discovery.

【Expected Research Achievements and Scientific Significance】

This project will contribute to the improvement of the reliability of computer software. Applications to data compression will also help solving the recent problem of the information explosion.

From an academic viewpoint, as higher-order model checking is related to a broad range of theoretical computer science, including program theory, formal languages, and complexity theory, the success of the project would have a big impact on the whole area of theoretical computer science. Applications to data complexity will also have an impact on other areas such as natural language processing and bioinformatics.

【Publications Relevant to the Project】

Naoki Kobayashi, Model Checking Higher-Order Programs, Journal of the ACM, 60(3), 62 pages, 2013.

Naoki Kobayashi, Kazutaka Matsuda, Ayumi Shinohara, Kazuya Yaguchi, Functional Programs as Compressed Data, Higher-Order and Symbolic Computation, 25(1), pp.39-84, 2012.

【Term of Project】FY2015-2019
【Budget Allocation】149,200 Thousand Yen

【Homepage Address and Other Contact Information】

http://www-kb.is.s.u-tokyo.ac.jp/~koba/