Some Studies on Language-Inclusion Problem

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1   The Aim of Research

Model checking is an automatic technique to verify whether a mathematical model M satisfies a given correctness requirement (or. specification) S. Usually, model M is given as a finite automaton or a pushdown automaton, and specification S is given as a finite automaton (i.e., S is *regular* specification). Thus, the model checking problem can be reduced to the language-inclusion problem $L(M) \subseteq L(S)$. Based on this approach, some model checkers have been successfully implemented in industry, e.g., SPIN and MOPED. While many analysis problems such as identifying dead code and accesses to uninitialized variables can be captured as regular specifications, many others require inspection of the stack or matching of calls and returns, are context-free. Although the model checking problem for context-free specifications is undecidable, algorithmic solutions have been proposed for checking many different kinds of non-regular requirements. Especially, Alur and Madhusudan [2] have proposed visibly pushdown automata (VPAs) as an adequate formalism for model checking context-free specifications. Different from pushdown automata, VPAs are closed under union, intersection, and complementation. The language-inclusion problem for VPAs is decidable in 2EXPTIME. Our research concentrates on the following problems:

– Study timed extension of VPAs and properties of this class of automata.
– Study determinizability and complementability of some extensions of VPAs such as 2-VPAs and visibly stack automata (VSAs).
– Revisit superdeterministic pushdown automata and the language-inclusion problem $L(A) \subseteq L(B)$, where A is an arbitrary PDA and B is a superdeterministic PDA.
– Study language-inclusion problem for VPAs using a heuristic technique to reduce time complexity.

2   Approach

We use automata and formal languages theory, timed automata, temporal logics, and automata-theoretic based verification.

3   Progress of 2007

– We introduce event-clock visibly pushdown automata (ECVPAs) as a proper extension of both event-clock automata and visibly pushdown automata.

The class of ECVPAs is sufficiently expressive to model real-time pushdown systems, and to specify common real-time non-regular context-free requirements. We show that ECVPAs are closed under union and intersection, and thus language inclusion problem is decidable for ECVPAs. Using these properties together with automata-theoretic approach, we prove that the model checking over visibly pushdown timed automata models against ECVPA specification is Exptime-complete.

– We also show that 2-Vpas and Vsas are not determinizable, 2-Vpas and Vsas are not complementable.

4   Future Direction

– Consider language-inclusion problem for Vpas using anti-chains approach. We hope to use this heuristic technique to avoid explicit determinization step in Alur and Madhusudan's algorithm. Then, we can reduce the complexity of language-inclusion problem for Vpas. After establishing theoretical results, we plan to implement a tool.
– We also plan to give a simple proof of Key Lemma of superdeterministic pushdown automata.
– For minor research, we consider to use the tool KCLP-HS to verify some duration properties for timed automata and hybrid systems.

5   Reports and Publications

– T. Nguyen and M. Ogawa. Alternated Stacking Technique Revisited: Inclusion Problem for Superdeterministic Pushdown Automata. Submitted to *IPSJ Transactions on Programming*.
– T. Nguyen and M. Ogawa. Event-clock Visibly Pushdown Automata. To submit to an international conference.
– T. Nguyen and M. Ogawa. Extensions of Determinization of VPAs are Difficult. To submit to *Information Processing Letters*.
– K. Kobayashi, T. Nguyen, and K. Hiraishi. Precomputation Based Approximate Algorithm for Model Predictive Control of Hybrid Systems. To submit to the *23rd International Technical Conference on Circuits/Systems, Computers and Communications*.

References

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2. R. Alur and P. Madhusudan. Visibly pushdown languages. In *STOC'04*, pp.202-211, 2004.
3. S. Greibach and E. P. Freimand. Superdeterministic PDAs: A Subcase with a Decidable Inclusion Problem. *Journal of the ACM*, Vol. 27(4), pp. 675-700, 1980.
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