Applications of the Existential Quantification Technique

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Bisimilarity checking of infinite-state systems has been an active and fascinating area of research for the last decade [1] and a number of original techniques were invented in order to explore the decidability barriers of strong and weak bisimilarity. Typical representatives of systems with unboundedly many reachable states are for example Pushdown Automata (PDA), Petri Nets (PN), Basic Process Algebra (BPA) and Basic Parallel Processes (BPP).

Recently, new techniques were developed to better classify the decidability and complexity aspects of bisimilarity checking for infinite-state systems. One of them is called the *existential quantification technique*. This technique was first used by Jančar [2] in the context of high undecidability of weak bisimilarity for PN and explicitly formulated by Srba in [3, 4]. The existential quantification technique gives the defender (in the usual bisimulation game) the possibility to make independent choices in case of nondeterministic branching.

The technique was beneficial for showing that strong bisimilarity of BPP [3] and later also of BPA [4] are PSPACE-hard problems. These proofs were achieved by polynomial time reductions from the problem of quantified boolean formula (QBF) and even though the classes BPA and BPP differ substantially in their capabilities, the proof strategies are similar. The reductions can be divided into two phases.

First, a quantified assignment of boolean variables is generated and the clauses of QBF satisfied by this assignment are remembered in the current states. Second, the condition that all clauses are satisfied is checked. It is the first (and the main) phase of assignment generation where the existential quantification technique is used. Moreover, this assignment generation is general enough to be uniformly described both for BPA and BPP. The only place where the proofs for BPA and BPP necessarily differ is in the second phase where the satisfied clauses are checked.

In this presentation we aim at providing a general meta-theorem which formally describes the sufficient conditions for process algebras to be capable of the assignment generation. We also present four applications in order to demonstrate the usefulness of the meta-theorem. The first two applications briefly repeat the PSPACE-hardness of strong bisimilarity for BPA and BPP. The third application deals with strong bisimilarity of normed PDA[1]. The last application proves a new result, namely PSPACE-hardness of weak bisimilarity for normed BPA.

References

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[1] This problem was very recently improved to EXPTIME-hardness (Kučera and Mayr, MFCS'02) — also by using the existential quantification technique.