More on Weak Bisimilarity of Normed Basic Parallel Processes

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Abstract. Deciding strong and weak bisimilarity of BPP are challenging because of the infinite nature of the state space of such processes. Deciding weak bisimilarity is harder since the usual decomposition property which holds for strong bisimilarity fails. Hirshfeld proposed the notion of bisimulation tree to prove that weak bisimulation is decidable for totally normed BPA and BPP processes. In this paper, we present a tableau method to decide weak bisimilarity of totally normed BPP. Compared with Hirshfeld’s bisimulation tree method, our method is more intuitive and more direct. Moreover from the decidability proof we can derive a complete axiomatisation for the weak bisimulation of totally normed BPP.

1 Introduction

A lot of attention has been devoted to the study of decidability and complexity of verification problems for infinite-state systems [1,15,16]. In [2], Baeten, Bergstra, and Klop proved the remarkable result that bisimulation equivalence was decidable for irredundant context-free grammars (without the empty product). Subsequently, many algorithms in this domain were proposed. In [7], Hans Hüttel and Colin Stirling proved the decidability of normed BPA by using a tableau method, which can also be used as a decision procedure. Decidability of strong bisimilarity for BPP processes has been established in [13]. Furthermore, [14] proved that deciding strong bisimilarity of BPP is PSPACE-complete.

For weak bisimilarity, much less is known. Semidecidability of weak bisimilarity for BPP has been shown in [5]. In [6] it is shown that weak bisimilarity is decidable for those BPA and BPP processes which are “totally normed”. P.Jančar conjectured that the method in [14] might be used to show the decidability of weak bisimilarity for general BPP. However, the problem of decidability of weak bisimilarity for general BPP is open.

Our work is inspired by Hirshfeld’s idea. In [6] Hirshfeld proposed the notion of bisimulation tree to prove the decidability of weak bisimulation of totally normed
BPP. Based on the idea, we show that weak bisimulation for totally normed BPP is decidable by a tableau method. In [13], S. Christensen, Y. Hirshfield and F. Moller proposed a tableau decision procedure for deciding strong bisimilarity of normed BPP. The key for tableau method to work is a nice decomposition property which holds for strong bisimulation, but fails for weak bisimulation. In our work, instead of using decomposition property, we apply Hirshfeld’s idea to control the size of the tableaux to make the tableau method work correctly. This approach not only provides us a more direct decision method, but also has the advantage of providing a completeness proof of an equational theory for weak bisimulation of totally normed BPP processes, similar to the tableau method of [13] provides such a completeness proof for strong bisimulation of normed BPP processes. Moreover, the termination proof for tableau is greatly simplified.

The paper is organized as follows. Section 2 introduces the notion of BPP processes and weak bisimulation and describes weak bisimulation equivalence. Section 3 gives the tableau decision method and presents the soundness and completeness results. In Section 4 we prove the completeness of the equational theory. Finally, Section 5 sums up conclusions and gives suggestions for further work.

2 BPP Processes and Weak Bisimulation Equivalence

Assuming a set of variables $\mathcal{V}$, $\mathcal{V}=\{X,Y,Z,\cdots\}$ and a set of actions $\mathcal{A}_\tau$, $\mathcal{A}_\tau=\{\tau,a,b,c,\cdots\}$ which contains a special element $\tau$, we consider the set of BPP expressions $\mathcal{E}$ given by the following syntax; we shall use $E,F,\ldots$ as metavariables over $\mathcal{E}$.

$$E ::= 0 \quad \text{(inaction)}$$

$$| X \quad \text{(variables, } X \in \mathcal{V})$$

$$| E_1 + E_2 \quad \text{(summation)}$$

$$| \mu E \quad (\mu \in \mathcal{A}_\tau)$$

$$| E_1|E_2 \quad \text{(merge)}$$

A BPP process is defined by a finite family of recursive process equations

$$\Delta = \{ X_i \overset{\text{def}}{=} E_i | 1 \leq i \leq n \}$$

where the $X_i \in \mathcal{V}$ are distinct variables and each $E_i$ is BPP expressions, and free variables in each $E_i$ range over set $\{X_1,\ldots,X_n\}$. In this paper, we concentrate on guarded BPP systems.

**Definition 1.** A BPP expression $E$ is guarded if each occurrence of variable is within the scope of an atomic action, and a BPP system is guarded if each $E_i$ is guarded for $1 \leq i \leq n$.

**Definition 2.** The operational semantics of a guarded BPP system can be simply given by a labeled transition system $(\mathcal{S}, \mathcal{A}_\tau, \rightarrow)$ where the transition relation $\rightarrow$ is generated by the rules in Table 1.