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Electronic Notes in Theoretical Computer Science

ELSEVIER Electronic Notes in Theoretical Computer Science 122 (2005) 211–228

www.elsevier.com/locate/entcs

Weak Bisimulation for Action-Type Coalgebras (Extended Abstract)

Ana Sokolova[1,2]

Department of Mathematics and Computer Science
Eindhoven University of Technology, TU/e
Eindhoven, The Netherlands

Erik de Vink[3]

Department of Mathematics and Computer Science
Eindhoven University of Technology, TU/e
LIACS Leiden University
Eindhoven, Leiden, The Netherlands

Harald Woracek[4]

Department of Analysis and Scientific Computing
TU Vienna
Vienna, Austria

Abstract

We propose a coalgebraic definition of weak bisimulation for a class of coalgebras obtained from bifunctors over the category Set. Weak bisimilarity for a system is obtained as strong bisimilarity of a transformed system. The transformation consists of two steps: First, the behaviour on actions is expanded to behaviour on finite words. Second, the behaviour on finite words is taken modulo the hiding of invisible actions, yielding behaviour on equivalence classes of words closed under silent steps. The coalgebraic definition is justified by two correspondence results, one for the classical notion of weak bisimulation of Milner and another for the notion of weak bisimulation for generative probabilistic transition systems as advocated by Baier and Hermanns.

Keywords: coalgebra, bisimulation, weak bisimulation, labeled transition system, generative probabilistic transition system

doi:10.1016/j.entcs.2004.06.050

1 Introduction

In this paper we present a definition of weak bisimulation for action-type systems. A typical example of an action-type system is the familiar labelled transition system (LTS) (see, e.g., [20,18]), but also many types of probabilistic systems (see, e.g., [16,27,11,3,26]) fall into this class. In order to emphasize the role of the actions we view coalgebras as arising from bifunctors over the category Set.

In the verification of properties of a system, strong bisimilarity is often too strong an equivalence. Weak bisimilarity [17,18] is a looser equivalence on systems that abstracts away from invisible steps. It is well-known that, in the concrete case of weak bisimilarity for a labelled transition system $\mathcal{S}$, amounts to strong bisimilarity on the 'double-arrowed' system $\mathcal{S}''$ induced by $\mathcal{S}$. We exploit this idea in formulating a general coalgebraic definition of weak bisimilation. Our approach, given a system $\mathcal{S}$, consists of two stages:

(i) First, we define a '$*$-extension' $\mathcal{S}'$ of $\mathcal{S}$ which is a system with the same state set as $\mathcal{S}$, but with action set A^*, the set of all words over A. The system $\mathcal{S}'$ captures the behaviour of $\mathcal{S}$ on finite traces.

(ii) Next, we fix a set of invisible actions $\tau \subseteq A$ and transform $\mathcal{S}'$ into a 'weak-τ-extension' $\mathcal{S}''$ which abstracts away from τ steps. Then we define weak bisimilarity on $\mathcal{S}$ as strong bisimilarity on the weak-τ-extension $\mathcal{S}''$.

In the context of concrete probabilistic transition systems, there have been several proposals for a notion of weak bisimulation, often relying on the particular model under consideration. Segala [27,26] proposed four notions of weak relations for his model of simple probabilistic automata. Baier and Hermanns [3,2,4] have given a rather appealing definition of weak bisimulation for the case of generative probabilistic systems. Philippou, Lee and Sokolsky [21] studied weak bisimulation in the setting of the alternating model [14]. This work was extended to infinite systems by Desharnais, Gupta, Jagadeesan and Panangaden [9]. Desharnais et al. also provided a metric analogue of weak bisimulation [8].

Here, we work in a coalgebraic framework and use the general coalgebraic apparatus of bisimulation [1,15,25]. For weak bisimulation in this setting, there has been early work by Rutten on weak bisimulation for while programs [24] succeeded by a syntactic approach to weak bisimulation by Rothe [23]. In the latter paper, weak bisimulation for a particular class of

[1] Research supported by the PROGRESS project ESS.5202, (a)MaPAoTS
[2] Email: a.sokolova@tue.nl
[3] Email: evink@win.tue.nl
[4] Email: harald.woracek@tuwien.ac.at