Bisimilarity and Behaviour-Preserving Reconfigurations of Open Petri Nets*

Paolo Baldan[1], Andrea Corradini[2], Hartmut Ehrig[3], Reiko Heckel[4], and Barbara König[5]

[1] Dipartimento di Matematica Pura e Applicata, Università di Padova, Italy
[2] Dipartimento di Informatica, Università di Pisa, Italy
[3] Institut für Softwaretechnik und Theoretische Informatik, Technische Universität Berlin, Germany
[4] Department of Computer Science, University of Leicester, UK
[5] Abteilung für Informatik und Angewandte Kognitionswissenschaft, Universität Duisburg-Essen, Germany

Abstract. We propose a framework for the specification of behaviour-preserving reconfigurations of systems modelled as Petri nets. The framework is based on open nets, a mild generalisation of ordinary Place/Transition nets suited to model open systems which might interact with the surrounding environment and endowed with a colimit-based composition operation. We show that natural notions of (strong and weak) bisimilarity over open nets are congruences with respect to the composition operation. We also provide an up-to technique for facilitating bisimilarity proofs. The theory is used to identify suitable classes of reconfiguration rules (in the double-pushout approach to rewriting) whose application preserves the observational semantics of the net.

1 Introduction

Petri nets are a well-known model of concurrent and distributed systems, widely used both in theoretical and applicative areas [19]. In classical approaches, nets are intended to represent closed, completely specified systems evolving autonomously through the firing of transitions. Therefore, ordinary Petri nets do not support directly certain features that are needed to model *open* systems, namely systems which can interact with the surrounding environment or, in a different view, systems which are only partially specified.

Firstly, a large (possibly still open) system is typically built out of smaller open components. Syntactically, an open system is equipped with suitable interfaces, over which the interaction with the external environment can take place. Semantically, openness can be represented by defining the behaviour of a component as if it were embedded in general environments, determining any possible interaction over the interfaces.

* Research partially supported by the EU IST-2004-16004 SENSORIA, the MIUR Project ART, the DFG project SANDS and CRUI/DAAD VIGONI "Models based on Graph Transformation Systems: Analysis and Verification".

T. Mossakowski et al. (Eds.): CALCO 2007, LNCS 4624, pp. 126–142, 2007.

Secondly, often the building components of an open system are not statically determined, but they can change during the evolution of the system, according to predefined reconfiguration rules triggered by internal or external solicitations.

In this paper we present a framework where open systems can be modelled as Petri nets. Observational semantics based on (weak) bisimulation are shown to be congruences with respect to the composition operation defined over Petri nets. Building on this, suitable reconfigurations of such systems can be specified as net rewritings, which preserve the behaviour of the system.

The framework is based on so-called *open nets*, a mild generalisation of ordinary Petri nets introduced in [2,3] to answer the first of the requirements above, i.e., the possibility of interacting with the environment and of composing a larger net out of smaller open components. An open net is an ordinary net with a distinguished set of places, designated as open, through which the net can interact with the surrounding environment. As a consequence of such interaction, tokens can be freely generated and removed in open places. In the mentioned papers open nets are endowed with a composition operation, characterised as a pushout in the corresponding category, suitable to model both interaction through open places and synchronisation of transitions.

In the first part of the paper, after having extended the existing theory for open nets to deal with *marked* nets, we introduce bisimulation-based observational equivalences for open nets. Following the intuition about reactive systems discussed in [12], such equivalences are based on the observation of the interactions between the given net and the surrounding environment. The framework treats uniformly *strong bisimilarity*, where every transition firing is observed, and *weak bisimilarity*, where a subset of unobservable transition labels is fixed and the firings of transitions carrying such labels are considered invisible. Bisimilarity is shown to be a congruence with respect to the composition operation over open nets. Interestingly enough, this holds also when the set of non-observable labels is not empty, i.e., for weak bisimilarity: some natural questions regarding the relation with weak bisimilarity in CCS are also addressed. In addition, we also define an up-to technique for facilitating bisimulation proofs.

Exploiting the results in the first part of the paper we introduce a framework for open net reconfigurations. The fact that open net components are combined by means of categorical colimits, suggests a setting for specifying net reconfigurations, based on double-pushout (DPO) rewriting [9]. Using the congruence result for bisimilarity we identify classes of transformation rules which ensure that reconfigurations of the system do not affect its observational behaviour.

A concluding section discusses some related work. A full version of the paper, with proofs and additional results, is available as [4].

2 Marked Open Nets

An *open net*, as introduced in [2,3], is an ordinary P/T Petri net with a distinguished set of *open places*, which represent the interface through which the environment can interact with the net. An open place can be an *input place*,