Modelling and simulation of asynchronous real-time systems using Timed Rebeca

Arni Hermann Reynisson, Marjan Sirjani *, Luca Aceto, Matteo Cimini, Ali Jafari, Anna Ingolfsdottir, Steinar Hugi Sigurdarson

School of Computer Science, Reykjavik University, Reykjavik, Iceland

HIGHLIGHTS

• Timed Rebeca as an actor-based modelling language extended with time constraints.
• The formal semantics of Timed Rebeca using Structural Operational Semantics (SOS).
• A tool for mapping Timed Rebeca models to Erlang.
• Examples of applications of Timed Rebeca to different small and medium sized case studies.
• Experimental results from the simulation of the resulting Timed Rebeca models using McErlang.

ARTICLE INFO

Article history:
Received 31 January 2012
Received in revised form 20 January 2014
Accepted 21 January 2014
Available online 24 January 2014

Keywords:
Concurrent system
Timing constraints
Distributed systems
Actor modelling
Analysis

ABSTRACT

In this paper we propose Timed Rebeca as an extension of the Rebeca language that can be used to model distributed and asynchronous systems with timing constraints. Timed Rebeca restricts the modeller to a pure asynchronous actor-based paradigm, where the structure of the model represents the service oriented architecture, while the computational model matches the network infrastructure. The modeller can specify both computational and network delay, and assign deadlines for serving a request. We provide the formal semantics of the language using Structural Operational Semantics, and show its expressiveness by means of examples. We developed a tool for automated translation from Timed Rebeca to the Erlang language, which provides a first implementation of Timed Rebeca. We can use the tool to set the parameters of Timed Rebeca models, which represent the environment and component variables, and use McErlang to run multiple simulations for different settings. The results of the simulations can then be employed to select the most appropriate values for the parameters in the model. Simulation is shown to be an effective analysis support, specially where model checking faces almost immediate state explosion in an asynchronous setting.

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1. Introduction

This paper presents an extension of the actor-based Rebeca language [1,2] that can be used to model distributed and asynchronous systems with timing constraints. This extension of Rebeca is motivated by the ubiquitous presence of real-time computing systems, whose behaviour depends crucially on timing as well as functional requirements.

A well-established paradigm for modelling the functional behaviour of distributed and asynchronous systems is the actor model. This model was originally introduced by Hewitt [3] as an agent-based language, and is a mathematical model of concurrent computation that treats actors as the universal primitives of concurrent computation [4]. In response to a message that it receives, an actor can make local decisions, create more actors, send more messages, and determine how

* Corresponding author.

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http://dx.doi.org/10.1016/j.scico.2014.01.008
Comparison with other timed actor models

We know of a few other timed actor-based modelling languages [16-18] that we will discuss in more detail in Section 6, where we discuss further related work. In [16] a central synchronizer acts like a coordinator and enforces the real-time and synchronization constraints (called interaction constraints). A language for the coordinated actors is briefly proposed in [17]; however, the main focus is having reusable real-time actors without hardwired interaction constraints. The constraints declared within the central synchronizer in this line of work can be seen as the required global properties of a Timed Rebeca model. We capture the architecture and configuration of a system via a Timed Rebeca model and then we can check whether the global constraints are satisfied. The language primitives that we use to extend Rebeca are consistent with the proposal in [17]. The primitives proposed in [18] are different from ours; that paper introduced an await primitive whereas we keep the asynchronous nature of the model.

Analysis support

In order to analyze Timed Rebeca models, we developed a tool to facilitate their simulation. In a parallel project [19], a mapping from Timed Rebeca to timed automata is developed and UPAPAAL [20] is used for model checking. The asynchronous nature of Rebeca models causes state explosion while model checking even for small models. One solution is using a modular approach like in [21]. Here, we selected an alternative solution as a complementary tool for analysis. Using our tool we can translate a Timed Rebeca model to Erlang [22], set the parameters which represent the environment and component variables, and run McErlang [9] to simulate the model. The tool allows us to change the settings of different timing parameters and rerun the simulation in order to investigate different scenarios, find potential bugs and problems, and optimize the model by manipulating the settings. The parameters can be timing constraints on the local computations (e.g., deadlines for accomplishing a requested service), computation time for providing a service, and frequency of a periodic event. Parameters can also represent network configurations and delays. In our experiments we could find timing problems that caused missing a deadline, or an unstable state in the system.
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