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Performance Evaluation of a Real-time Simulation Architecture using Probabilistic Model Checking

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Abstract

The goal of this paper is to show how to use probabilistic model checking techniques in order to achieve quantitative performance evaluation of a real-time distributed simulation. A simulation based on the *High Level Architecture* (HLA) is modelled as a stochastic process, a *Continuous Time Markov Chain* (CTMC), using the stochastic algebra PEPA. Next a property representing a performance constraint is evaluated applying *Continuous Stochastic Logic* CSL formula on the CTMC model using the probabilistic model checker PRISM. Finally a first experiment is made to compare the model with a real case.

Keywords: real-time distributed simulation, probabilistic model checking, performance evaluation, PEPA, PRISM.

1 Introduction

Real-time simulations are under heavy time constraints. The particularity of a real-time simulation is that the logical time of the simulation must be the same as the real one. To keep the real and logical time equal, the computation of the simulation must be fast enough. In order to get enough computation power, a simulation used to be split into several smaller simulations distributed across different machines. Unfortunately the smaller simulations lose the global view of the system and need to collect enough data from each-other's simulations. A middleware, *High Level Architecture* (HLA), is devoted to realising these

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exchanges of data carried by a network. The problem here is that the network and the middleware induces some delay in their communications which can hamper the realism of the simulation. In order to know if a distributed simulation is going to behave correctly, certain time constraints need to be checked.

The aim of this paper is to show how a distributed simulation can be modelled as a probabilistic process in order to verify, using probabilistic model checking techniques, whether or not some required constraints are satisfied by the system. These constraints cannot always hold due to the intrinsic nature of the system, but can however be expected to hold in a majority of execution cases with reasonable confidence. The probabilistic modelling permits the quantification of this confidence and allows the representation of complex behaviours in a simpler way. For example, in the modelling of a network it is not necessary to model how a message gets lost but only the probability that the message gets lost.

To achieve this purpose, a HLA distributed simulation is modelled in a stochastic process, a *Continuous Time Markov Chain* (CTMC). Then, the *Continuous Stochastic Logic* (CSL) is used to formalise performance constraints required by the simulation to behave correctly. The probabilistic model checker PRISM allows the construction of the CTMC model and the verification that a CSL formula is satisfied by the CTMC model.

The remainder of this paper is organised as follows. Section 2 recalls the preliminary notions needed in the course of the paper : *High Level Architecture* (HLA), *Continuous Time Markov Chain* (CTMC) and the stochastic algebra PEPA *(Performance Evaluation Process Algebra)*, *Continuous Stochastic Logic* (CSL) and the software PRISM. Section 3 describes a case study of a real-time distributed simulation based on HLA, explains in detail the CTMC modelling using PEPA. Section 4 contains a time constraint formalised in CSL needed to be verified by the model and section 5 the obtained results with the model checker PRISM. Section 6 contains comparison with the model and a real simulation case. Finally, Section 7 gives some conclusions and future directions of the work.

2 Fundamental concepts

2.1 The HLA architecture

The High Level Architecture (HLA) provides the specification of a common technical architecture to combine multiple simulations into a larger simulation.