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Stochastic models for quality of service of component connectors

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Abstract

The intensifying need for scalable software has motivated modular development and using systems distributed over networks to implement large-scale applications. In Service-oriented Computing, distributed services are composed to provide large-scale services with a specific functionality. In this way, reusability of existing services can be increased. However, due to the heterogeneity of distributed software systems, software composition is far from trivial, and requires additional mechanisms to impose some form of a coordination on a distributed software system. For this purpose, a number of coordination languages have been proposed, such as Reo, Linda, and Orc.

Besides functional correctness, a composed service must satisfy various quantitative/non-functional requirements for its clients, which are generically called its quality of service (QoS). For instance, although a number of services may offer the same functionality, some of them may accommodate tight deadlines, but others may not. In particular, it is tricky to obtain the overall QoS of a composed service even if the QoS information of its constituent distributed services is given.

In this thesis, Stochastic Reo is proposed, a formalism to specify software composition with QoS aspects. Stochastic Reo is an extension of Reo, a channel/connector-based coordination language, with associated stochastic values which indicate the frequency of I/O interactions and internal processing delays within connector primitives.

As a semantic model of Stochastic Reo, we propose two different automata models, namely, Quantitative Intentional Automata and Stochastic Reo Automata. Stochastic Reo Automata are compositional, which enables us to obtain the automata model of a complex connector by composing the automata models of its constituent primitive connectors. A formal proof of compositionality is included in the thesis. These two semantic models are also used as intermediate models in order to generate their corresponding stochastic models, especially, Continuous-time Markov Chains (CTMCs) and Interactive Markov Chains. These stochastic models can be used for practical analysis of the underlying connectors.

Based on this theory, we have implemented the tool *Reo2MC* as a plug-in within the Reo toolset, Extensible Coordination Tools. Reo2MC generates CTMCs corresponding to Reo connectors, which are given to or drawn in the tool, via the semantic models of the Reo connectors.

As a case study, we have modeled and analyzed the ASK system using Reo2MC. The ASK system is an industrial software developed by the Dutch company Almende. Its analysis results provided the best cost-effective resource utilization and some suggestions to improve the performance of the ASK system. For example, the results provided suggestion of the required minimum capacity of a task queue and detected some bottlenecks in the system.

In summary, this thesis proposes formal models to specify the behavior of connectors coordinating distributed software over a network, and to reason about the end-to-end QoS properties of the connectors. This thesis also shows how to translate the semantic models of connectors into their corresponding stochastic models for further analysis. The theoretical results obtained in this thesis have been implemented and integrated as a plug-in into an existing tool set. The practical relevance of the approach is demonstrated by modeling and analyzing a large industrial software using the tool, which resulted in improvements to the analyzed system.