Feature-Oriented Modelling and Analysis of a Self-Adaptive Robotic System

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Abstract

This one-page document summarises a paper published in FAC [1].

CCS Concepts

• **Software and its engineering** → **Software product lines**; **Formal methods**; **Model checking**; • **Computer systems organization** → **Embedded and cyber-physical systems**; **Robotics**; • **Mathematics of computing** → **Probabilistic representations**; • **Theory of computation** → **Verification by model checking**.

Keywords

Feature models, Probabilistic model checking, Parametric model checking, Self-adaptive systems, Cyber-physical systems, Robotics

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We show how self-adaptive systems (SASs) can be formally modelled and analysed using techniques introduced for software product lines (SPLs), focusing on the different aspects of the SAS that can be analysed using this approach and the different kinds of analysis.

SASs can be realised as two-layered systems with a *managed subsystem* implementing the application logic and a *managing subsystem* implementing the adaptation logic: the managing subsystem receives input from the managed subsystem and the environment, reasons about it and adapts the managed subsystem if necessary. We use a case study of an autonomous underwater vehicle (AUV) with the mission to find and inspect a pipeline to illustrate how to use techniques from SPLs to model and analyse SASs.

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Concretely, we model the variability of the managed subsystem in a feature model, its behaviour as a probabilistic featured transition system, and the managing subsystem as a feature controller switching between features (and thereby adapting the managed subsystem). By including probabilistic behaviour, uncertainties in system operation as well as the environment can be reflected. To showcase the analyses enabled by this approach, we implemented our case study [2] in ProFeat [3], a tool for family-based probabilistic model checking, which enables to model check properties of all configurations and re-configurations of the SAS in one single run.

A ProFeat model can automatically be translated into PRISM's input language to facilitate probabilistic analysis with different model checkers. We showcase analysis with the probabilistic model checkers PRISM and Storm. The analysis of our case study in ProFeat concerned five different aspects: (1) safety guarantees for the AUV's mission duration and energy usage, where the focus lies on the difference of the analysis results in different scenarios and with distinct environments; (2) safe and unsafe states of the model; (3) the impact of different environments on the safety guarantees; (4) how environmental forces influence the operation of the AUV; and (5) trade-offs between the AUV's mission duration and its energy usage. We harvest state-of-the-art analysis capabilities of probabilistic model checking by analyses including quantitative, parametric, and multi-objective probabilistic model checking.

We thus provide a comprehensive overview of the analyses enabled by our proposed approach for formally modelling and analysing SASs with techniques introduced for SPLs. We show that our approach enables the analysis of a variety of aspects of an SAS, while maintaining the separation of concerns between its application and adaptation logic. We also discuss the suitability of SPL techniques and tools for modelling and analysing SASs.

References

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