Chapter 23
Model-Based Testing of Highly Configurable Embedded Systems

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ABSTRACT

This chapter reports the results of a cycle computer case study and a previously conducted industrial case study from the automation domain. The key result is a model-based testing process for highly configurable embedded systems. The initial version of the testing process was built upon parameterizeable systems. The cycle computer case study adds the configuration using the product line concept and a feature model to store the parameterizable data. Thus, parameters and their constraints can be managed in a very structured way. Escalating demand for flexibility has made modern embedded software systems

DOI: 10.4018/978-1-5225-3923-0.ch023

highly adjustable. This configurability is often realized through parameters and a highly configurable system possesses a handful of those. Small changes in parameter values can often account for significant changes in the system's behavior, whereas in some other cases, changed parameters may not result in any perceivable reaction. The case studies address the challenge of applying model-based testing to configurable embedded software systems in order to reduce development effort. As a result of the case studies, a model-based testing process was developed. This process integrates existing model-based testing methods and tools such as combinatorial design and constraint processing as well as the product line engineering approach. The testing process was applied as part of the case studies and analyzed in terms of its actual saving potentials, which turned out to reduce the testing effort by more than a third.

INTRODUCTION

In the automation domain, large and complex systems like chemical or power plants are common practice. The products of these plants are part of our daily lives, and our living standard depends directly on their reliable supply. This dependency accounts for the *high quality* requirements for these plants, which adds to the burden of voluminous costs for engineering and operation. Of course, such *high quality* is required for almost all of the components of a plant in order to ensure the proper functioning up to the point that even certain failures should not lead to unbearable consequences. On the upper level, *control systems* based on workstation platforms (e.g. Microsoft Windows®) are used to control the overall function of the plant, for example the generation of energy in a power plant. Between the control system layer and the lowest sensor and actuator level, several layers of embedded systems of varying complexity are used to collect and pass on sensor data (like temperature or pressure values), monitor the proper function of plant sub modules and actuate upon requests from the upper level *control system* (e.g., close a valve).

The main challenge in the application of model-based testing for embedded systems is their simple behavior visible from the outside, which internally gets dramatically complex due to configurable features and parameters. Each system has many parameters and within this system, a *configuration* is a set of parameters with concrete values selected for each parameter. Such configurations are intended for various purposes, for example for dealing with different modes of operation, different types of user interactions, error and exception handling etc. Different kinds of system behavior are directly related to configurations and as a result, the verification of the system is cumbersome and difficult as the number of available configurations rises.

This article presents the results of the industrial automation domain case study of the ITEA2-project D-MINT (http://www.d-mint.org), driven by ABB. The resulting testing process was and the elaborated model based testing approach applied to a cycle computer at the Technische Universität Ilmenau. Here, the concept of product lines has been added to the testing process resulting in a reduction of relevant parameters for the parameter model since those parameter can be moved into the feature model.

The case studies aimed at answering questions regarding the most promising model-based testing methods and tools as a way of addressing the goal of reduced testing efforts. In addition, the questions of how and when to apply model-based testing were answered and ultimately led to a new and holistic view on model-based testing for embedded systems, based on (Bauer, Eschbach, Groessl, Hussain, Streitferdt, & Kantz, 2009). Finally, the case studies deliver an analysis and precise numbers of the actual savings as a result of applying the developed model-based testing process.

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