Chapter 6
Model-Based Testing of Highly Configurable Embedded Systems in the Automation Domain

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ABSTRACT

This article reports the results of an industrial case study demonstrating the efficacy of a model-based testing process in assuring the quality of highly configurable systems from the automation domain. Escalating demand for flexibility has made modern embedded software systems highly configurable. This configurability is often realized through parameters and a highly configurable system possesses a handful of those. Small changes in parameter values can account for significant changes in the system’s behavior, whereas in other cases, changed parameters may not result in any perceivable reaction. This case study addresses the challenge of applying model-based testing to configurable embedded software systems to reduce development effort. As a result of the case study, a model-based testing process was developed and tailored toward the needs of the automation domain. This process integrates existing model-based testing methods and tools, such as combinatorial design and constraint processing. The testing process was applied as part of the case study and analyzed in terms of its actual saving potentials, which reduced the testing effort by more than a third.

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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 work-station 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 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 case study 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 within this domain were answered and ultimately led to a new and holistic view on model-based testing for embedded systems in the automation domain, based on (Bauer, Eschbach, Groessl, Hussain, Streitferdt, & Kantz, 2009). Finally, the case study delivers an analysis and precise numbers of the actual savings as a result of applying the developed model-based testing process.

In the section “Softstarter Example”, the soft-starter is introduced as an example of an embedded device in the automation domain and a basis for the case study. In the section “Model-Based Testing Process for Embedded Devices in the Automation Domain”, the integrated testing process is discussed as a key concept of the case study. In the section “Evaluation of the Approach”, the results of applying the process in the case study are presented. In section “Related Work”, an overview of the relevant testing technologies and methods is given. Finally, this article concludes with a brief summary and topics for further research.

SOFTSTARTER EXAMPLE

Electric motors are common actuators in process automation. For this article, the starting and the stopping of an electric motor is taken as example. The device used in this article is a softstarter as shown in Figure 1, which is used to smoothly ramp up/down a motor. This functionality is needed for large motors where the peak current consumption
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