Model-Based Engineering of Embedded Systems

The SPES 2020 Methodology

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Preface

Embedded systems — opportunities and challenges

Embedded systems have long become an essential part of our everyday life. They control essential features in our cars, such as airbags, braking systems, or power locks, and are used to manage our steadily increasing communication needs by means of Internet routers or cell phones. Embedded systems are essential in application areas where human control is impossible or infeasible, such as adjusting the control surfaces of aircraft or controlling a chemical reaction inside a power plant. The embedded systems industry has therefore become a multibillion euro industry.

The development of modern embedded systems is becoming increasingly difficult and challenging. Issues that greatly impact their development include the increase in the overall system complexity, their tighter and cross-functional integration, the increasing requirements concerning safety and real-time behavior, the need to reduce development and operation costs, as well as the need for shorter time-to-market.

Need for an integrated development approach

Many research contributions and development methods aim to address these challenges, and theories for the seamless development of embedded systems have been proposed. However, these solutions address only a small subset of the above-mentioned problems, are only applicable in very specific settings, and lack an appropriate cross-domain validation in representative industrial settings.

The mission of the Software Platform Embedded Systems 2020 (SPES 2020) project was thus to focus on the professionalization of a cross-domain, model-based development method for embedded systems. SPES 2020 is an innovation alliance project sponsored by the German Federal Ministry of Education and Research. In SPES 2020, 21 partners from academia and industry have joined forces in order to develop a modeling framework that is based on the latest state-of-the-art in embedded systems engineering, addresses specific development challenges, and is validated in different domains to ensure its applicability in industrial embedded systems development.

Aim of this book

Industry challenges, principles, and application

The purpose of this book is to present an overview of the SPES modeling framework and to demonstrate its applicability to embedded system development in various representative industry domains. The book provides a comprehensive explanation of the basic solution concepts of the SPES modeling framework and illustrates the application of these concepts in five application domains (automation, automotive, avionics, energy, and healthcare). The book summarizes the lessons learned, outlines evaluation results, and describes how the SPES 2020 modeling framework can be tailored to meet domain-specific and project-specific needs.

Target audience

Researchers, practitioners, and consultants

This book is aimed at professionals and practitioners who deal with the development of embedded systems on a daily basis. This includes developers, requirements engineers, software or hardware architects, business analysts, mechatronics experts, safety engineers, testers, and certifiers. It serves as a compendium for researchers in the field of software engineering and embedded systems, regardless of whether you are working for a research division of a company or are employed with a university or academic research institute. For teachers and consultants, it provides a sound foundation in the basic relationships and solution concepts for engineering embedded systems and illustrates how these principles and concepts can be applied in practice.

Content of this book

This book is structured into four parts and 18 chapters:

Status quo and industry requirements

- *Part I – Starting Point:* This part discusses the status quo of embedded system development and model-based engineering and summarizes the key requirements faced when developing embedded systems in different application domains. Chapter 1 gives detailed insight into the role of embedded systems and outlines the scope of the SPES 2020 project. Chapter 2 discusses and summarizes the requirements for the development of future embedded system development in the automation, automotive, avionics, energy, and healthcare application domains.

The SPES modeling framework and its viewpoints

- *Part II – The SPES modeling framework:* This part describes the backbone of SPES 2020 — the SPES modeling framework. Chapter 3 derives the core principles of the SPES 2020 modeling framework and illustrates how these principles help in fulfilling the

requirements outlined in Chapter 2. It outlines the overall SPES modeling framework and describes the basic solution concepts of the SPES 2020 abstraction layers and viewpoints. Subsequently, Chapters 4 through 7 describe the requirements, functional, logical, and technical viewpoints of the SPES modeling framework. Each chapter defines the specific engineering artifacts subsumed by the viewpoint, outlines the basic relationships of those artifacts with the other viewpoints, and describes the engineering process across the basic abstraction layers. Chapters 8 and 9 describe how the SPES modeling framework addresses the crosscutting aspects "safety" and "real-time."

Evaluation strategy and application details

- *Part III – Application and Evaluation of the SPES Modeling Framework:* This part describes the validation steps taken to ensure that the requirements outlined in Chapter 2 are met by the solution concepts proposed in Part II. Chapter 10 outlines the overall evaluation strategy used to assess the applicability of the SPES modeling framework. Chapters 11 through 15 describe the use of the SPES modeling framework in the five application domains automation, automotive, avionics, energy, and healthcare. Each of these chapters briefly characterizes the specifics of the application domain and shows how the SPES modeling framework can be tailored with regard to these characteristics. In addition, each chapter outlines the evaluation activities conducted in the application domain by various partners and summarizes the key evaluation results. Chapter 16 summarizes the overall evaluation results and discusses them in the context of the requirements outlined in Chapter 2 and the SPES principles described in Chapter 3.

Achieved results and future work

- *Part IV – Impact of the SPES Modeling Framework:* This part assesses the impact of the SPES modeling framework. Chapter 17 summarizes the key lessons learned in SPES 2020. Chapter 18 concludes this book by providing insights into open challenges for the engineering of software-intensive embedded systems.

For further reading, a list of relevant, advanced literature providing deeper insights is given at the end of each chapter.

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