Preface

Today, embedded systems are ubiquitous in our everyday life, in cell phones and washing machines, but also in cars and even medical equipment. With this escape from their former habitat within desktop computers, these systems are increasingly interacting with their environment: Sensors measure physical phenomena such as temperature, acceleration, or magnetic fields, while actors manipulate the outside world, like in robots or electronically controlled combustion engines. The combination of an electronic system with a physical process is called a *cyber-physical system* (CPS).

With this paradigm, many new challenges need to be faced during modeling, design, implementation, verification, and test. For the design of hardware and software of CPS, new approaches need to be developed, taking into account non-functional requirements like energy efficiency and reliability even in harsh environments. Real-time aspects often play an important role. Furthermore, if a system is interacting with its physical environment, it becomes difficult to prove the functional correctness of the system. The combination of discrete and continuous behavior and the treatment of noisy sensor data are challenging problems.

Considering all the above aspects, CPS is an interdisciplicary topic, touching research areas such as computer science, robotics, electrical and mechanical enginieering, physics and more. In the *First International Summer School on Methods and Tools for the Design of Digital Systems*, we want to bring together experts from different fields of research and application. The goal of this summer school is to introduce PhD students to this exciting topic, and to offer them deeper insights into formal modeling and verification techniques. Regarding the application areas, the courses focus on robotics and space systems, as well as the railway domain and microfluidic biochips.

This summer school is organized by the *Graduate School System Design (SyDe)*. SyDe has been founded in 2012, funded by the German Excellence Initiative. It is a cooperation of the University of Bremen, the German Research Center for Artificial Intelligence (DFKI), and the German Aerospace Center (DLR). The graduate school provides a structured program for the formation of young researchers, bringing together PhD students from different working groups and research institutes that cover a wide range of scientific topics in hardware and system design, robotics and space systems. The summer school of 2015 is the third one organized by SyDe, and the first one open to international PhD students.

Overview. This book is divided into two parts. The first part contains the lecture notes, while the second part features selected short articles written by participating PhD students. The participants had been invited to submit a short report on their thesis projects. All submissions have undergone a review process.

The first three chapters discuss real-time and hybrid aspects, starting with *Verification of Embedded Real-time Systems*. There, Paula Herber and Sabine Glesner present a formalism for modeling real-time systems. In particular, they give semantics to SystemC models in terms of Timed Automata, and show how safety and timing properties can be verified.

In the second chapter, Frédéric Mallet introduces *MARTE/CCSL for Modeling Cyber-Physical Systems*. MARTE is a real-time extension of the UML. While the UML already provides a great variety of models and diagrams, important aspects of CPS are not captured by the standard. This chapter discusses how CPS can be modeled using appropriate extensions.

Goran Frehse gives *An Introduction to Hybrid Automata, Numerical Simulation and Reachability Analysis*. Hybrid automata are a popular formalism for the modeling of CPS, since they combine discrete and continuous aspects. Depending on the continuous dynamics of a modeled system, reachability computation can become very costly, and abstraction techniques are crucial in order to create scalable verification tools.

The following three chapters treat different aspects of verification and test. Here, it is discussed how classical methods from hardware and software verification can be applied on CPS, starting with *Model Checking and Model-Based Testing in the Railway Domain*. In this chapter, Anne Haxthausen and Jan Peleska show the integration of verification and test in an industrial context.

Modeling Unknown Values in Test and Verification is discussed in the following chapter by Bernd Becker et al. Unknown values occur frequently at the interfaces of components when following a component-based design style, or when systems are exposed to an uncertain environment, as is often the case for embedded systems and CPS. This chapter how formal techniques can be enhanced to treat such uncertainties without sacrificing exactness.

Complementary to static verification techniques, run-time monitoring is an important technique to ensure the proper functionality of complex systems. In the chapter *Specification of Parametric Monitors – Quantified Event Automata versus Rule Systems*, Klaus Havelund and Giles Reger give an overview on two parametric runtime verification systems. The formalisms are presented by means of an extensive suite of application examples, including the monitoring of a planetary rover.

The lecture notes are concluded with three chapters on practical applications of CPS, in the domains of biological micro-laboratories and robotics. Krishnendu Chakrabarty et al. present their recent *Advances in Design Automation Techniques for Digital-Microfluidic Biochips*. These systems combine electronics with biology, enabling the fast and cheap treatment of biological samples on a chip. This chapter presents the design of biochips, and how domain specific constraints can be treated.

The interaction between humans and robots is discussed in the chapter *Intuitive Interaction with Robots – Technical Approaches and Challenges* by Elsa Kirchner et al. Here, different research areas in the field of human-robot interaction are presented.

All chapters of the lecture notes contain extensive references to related work for further reading.

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We hope you will enjoy reading this book.

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