Cyber-Physical Systems Engineering: An Introduction

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Abstract. Cyber-Physical Systems (CPSs) [1] connect the real world to software systems through a network of sensors and actuators in which physical and logical components interact in complex ways. There is a diverse range of application domains [2], including health [3], energy [4], transport [5], autonomous vehicles [6] and robotics [7]; and many of these include safety critical requirements [8]. Such systems are, by definition, characterised by both discrete and continuous components. The development and verification processes must, therefore, incorporate and integrate discrete and continuous models.

The development of techniques and tools to handle the correct design of CPSs has drawn the attention of many researchers. Continuous modelling approaches are usually based on a formal mathematical expression of the problem using dense reals and differential equations to model the behaviour of the studied hybrid system. Then, models are simulated in order to check required properties. Discrete modelling approaches rely on formal methods, based on abstraction, model-checking and theorem proving. There is much ongoing research concerned with how best to combine these approaches in a more coherent and pragmatic fashion, in order to support more rigorous and automated hybrid-design verification.

It is also possible to combine different discrete-event and continuous-time models using a technique called co-simulation. This has been supported by different tools and the underlying foundation for this has been analysed. Thus, the track will also look into these areas as well as the industrial usage of this kind of technology.

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In this year's thematic track, we include papers that cover theoretical advances, ongoing research, industrial case-studies and tool/method development. The track will also include a session concerned with current challenges and research directions.

In *Intelligent Adaption Process in Cyber-Physical Production Systems* [9] (in this issue), the authors report on production and logistics systems, used in the manufacturing industry, and how Cyber-Physical Production System Models will help industry to improve on the key aspect of adaption—the production and logistics systems can be adapted more frequently, more precisely and more quickly when cyber-physical production systems are supporting the adaption process.

The article *Model-Based Systems Engineering for Systems Simulation* [10] (in this issue) propose a methodology for integrating simulation systems development with products systems engineering. This offers a better management and reuse of the various environment and mock-up models during system development. This general approach is independent both of the actual methods and tools used to model the system and of the simulation environment.

In *Scenario-based validation of automated driving systems* [11] (in this issue), the paper presents techniques for formalising test scenarios for automated driving systems. To assess the safety of such systems, all potentially critical situations have to be considered. The number of relevant scenarios is very large therefore testing must rely heavily on virtual, largely automatized exploration of scenario spaces. For that, classes of scenarios have to be described formally. The contribution delineates a general approach to safety assessment by virtual testing. It discusses in particular the nature and building blocks of a formal scenario language and the construction of test specifications.

In *Engineering of Cyber-Physical Systems in the automotive context: case study of a range prediction assistant* [12] (in this issue), the authors present a case study addressing the development of an assistant for estimating the range of an electric vehicle. The approach is based on the methodology and tools from the EU Horizon 2020 INTO-CPS project [13]. The paper promises an outlook on the development of similar tool chains for automotive planning. In summary, the paper shows that flexible and integrated tool-chains that rely on open standards for data exchange are key to efficient development of CPSs in the automotive domain.

The article *Testing Avionics Software: Is FMI up to the Task?* [14] (in this issue) compares the FMI and RT-Tester test engine architectures in the context of safety-critical avionics software. To do this, it uses one principal case study: a version of an aircraft controller application, synthesised from an existing system requirement.

The article *Co-simulation: the Past, Future, and Open Challenges* [15] (in this issue) provides an interesting historical overview of co-simulation, together with a couple of recent example of co-simulation technology, and some selected discussion points on directions in which the technology might evolve in future.

In *Lessons Learned Using FMI Co-Simulation for Model-based Design of Cyber Physical Systems* [16] (in this issue), the authors provide a critical analysis of the pros and cons of using FMI for model integration when co-simulation CPSs. The case study - a building Heating, Ventilation and Air Conditioning (HVAC) system – illustrates very well the advantages and disadvantages of the approach based on FMI.

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