A-CPS: Automation in High-performance Cyber Physical Systems Development

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Abstract. In this paper, we describe the Automation in High-performance Cyber Physical Systems Development research project. Its main goal is to contribute to the advancement of the state of the art in the model-based development of heterogeneous vehicular systems. In particular, the project aims at providing a model-based framework for the automatic assessment of timeliness of vehicular systems by means of model-based simulation, timing analysis and their interplay. Additional information on the project can be found through its official website: http://www.es.mdh.se/projects/520-Automation_in_High_performance_Cyber_Physical_Systems_Development

Keywords: Model-based software development, cyber physical systems, heterogeneous platforms, model-based timing verification.

1 Introduction

High-performance cyber-physical systems (CPS), like autonomous vehicles, are bringing computing into the new era of heterogeneous computing, where all the future computing platforms are likely to have several different computational units [13]. However, when different computing architectures are put together, one main challenge is to cope use the enormous computing capabilities, while still meeting several non functional criteria like timeliness and performance, to name a few. In particular, timeliness and its verification are of crucial importance for modern vehicles as they impact their safety and customer value. In order to tackle this challenge, the engineers not only need to write parallel software, but also cope with issues introduced by heterogeneity and parallelism, such as allocation of computations to computational units, that is an extremely complex task as it involves investigating the whole design space of possible allocations, which is typically infeasible without automation support. Today, at the best of our knowledge, there is little to no support for automating this task in the high-performance CPS development and these activities are mostly done manually, which makes them tedious, error-prone and inefficient. In this context, we believe that model-based techniques, such as modelling and model transformations, can be game changers in the development of high-performance CPS and particularly in supporting automatic timing verification [4]. Models could be employed for representing the software architecture and its timing-related properties while abstracting away from platform-specificity [3]. Model transformations could provide automation for the generation and optimisation of the design space of possible allocations [14]. This paper describes how the Automation in High-performance Cyber Physical Systems Development (A-CPS) research project contributes in tackling the challenge of introducing automation into the development of high-performance vehicular systems for providing automatic assessment of timing. A-CPS is a two year Swedish research project started in April 2019 and includes one academic partner, Mälardalen University (MDH), and two business partners, Arcticus Systems AB (AS) and Volvo Group Trucks Technologies (VGTT). A-CPS is funded by MDH, AS, VGTT and the Swedish Knowledge Foundation[1] (KKS) for a total of 1 893 776 Swedish kronor.

2 Project Team

The project team consists of three partners, namely MDH, AS and VGTT, which provide complementary competences in their respective domains. MDH is a world-leading university in the field of real-time systems research. The team from MDH includes the *project leader*, Dr. Alessio Bucaioni, and the *reference group* members namely Prof. Marjan Sirjani, Assoc. Prof. Cristina Seceleanu and Assoc. Prof. Patrizio Pellicione as external member from the Chalmers University of Technology (CTH) and University of Gothenburg (GU). Dr. Alessio Bucaioni has gained deep theoretical and practical background in model-driven engineering of embedded systems, especially regarding domain-specific modelling languages and automatic manipulations of system models for analysis purposes [4]. The research within A-CPS is conducted in the Industrial Software Engineering group headed by Prof. Jan Carlson. AS is a leading tool vendor for model-based software development of real-time embedded systems. It specialises in the vehicular domain and its tools have been used by the industry for over twenty years by world leading companies such as, e.g., Volvo Construction Equipment, BAE Systems, etc. AS contributes to A-CPS by supplying industrial needs, requirements and commercial tools. Dr. Kurt-Lennart Lundbäck represents AS in A-CPS. He is the founder and CEO of the company and his vast industrial experience and great expertise in real-time embedded systems and timing analysis bring an invaluable contribution to A-CPS. VGTT is the second-largest heavy-duty truck manufacturer in the world with heavy vehicles sold and serviced in more than 140 countries all over the world under several brands. The VGTT products are increasingly defined by software, and software related research and development is in strong growth within the company. In addition, the company has been successfully applying model-based software development to provide computer-control functionality in the vehicles for several years. VGTT contributes to A-CPS by supplying industrial needs, requirements and use cases. It contributes by proving the efficiency of the methods, techniques and results in the industrial setting, too. Dr. Henrik Lönn represents VGTT in A-CPS. He is an embedded software specialist with valuable experience and expertise as coordinator in national and European research projects.

3 Research Plan

In this section, we describe the A-CPS research goal, challenges, time plan, research methodology and expected outcomes.

[1] `https://www.kks.se`

3.1 Research Goal

The main goal of A-CPS is to provide a model-based framework for providing automatic assessment of timing for vehicular systems by means of model-based simulation, model-based timing analysis and their interplay. The proposed framework uses domain-specific modelling languages for representing the software architectures and its timing properties in terms structural and behavioural models. These models are platform-agnostic and do not carry allocation information. Model transformation translate these models into models ready for simulation and timing analysis. Such a translation involves the generation of models enriched with allocation information and it allows to exploit the computational power of heterogeneous platform while providing an automatic solution to the allocation challenge. Eventually, the observed results from the simulation and analysis are used for ensuring timing compliance of the vehicular system under development. As we aim at transferring the A-CPS results to industrial processes, the proposed framework leverages commercial and open-source languages as well as tools used in the vehicular segment. In particular, the modelling activities relies on the de-facto standard vehicular-specific modelling languages EAST-ADL [2] and AUTOSAR [1] and the commercial modelling language Rubus Component Model [8] (RCM). The timing analysis and simulation are carried out within the RCM integrated development environment, Rubus ICE, and the Eclipse Modelling Framework based tools Artop/EATOP, respectively.

3.2 Research Challenges

Towards the fulfilment of the project goal, we identify the following research challenges (RCs) to be tackled.

RC1: Modelling of software architecture and timing-related properties. As we leverage commercial and open-source modelling languages, the challenge is to investigate how to extend these languages without disrupting their technological assets.

RC2: Automation for assessment of timeliness. We want to monitor the timing-compliance of the vehicular system earlier in the development process and employ the observed values for taking evidence-based design decisions. To this end, the models of the software architecture and its timing-related properties must be enriched with allocation information and translated into models ready for the model-based simulation and analysis. This challenge can be broken down into three sub-challenges.

RC2.1: Automation for simulation-based assessment of timeliness. The challenge is how to generate models for simulation starting from the structural and behavioural models.

RC2.2: Automation for timing analysis. The challenge is how to generate the whole set of meaningful models entailing different allocations.

RC2.3: Automation for back-propagation. The challenge is how to use the observed values for providing guidance to the engineer for taking evidence-based design decisions.

3.3 Time Plan

In order to tackle the above mentioned RCs, we divide A-CPS into 6 project phases (PPs) as follows. PP1: identification and specification of requirements and use cases, PP2: identification of modelling concepts for high-performance vehicular systems, PP3: automation for simulation-based assessment of timing, PP4: automation for timing analysis, PP5: back-propagation and exploitation of observed values and PP6: validation and dissemination of results. Fig. 1 shows a summary of time plan for the different PPs. A-CPS starts in April 2019 and ends in March 2021.

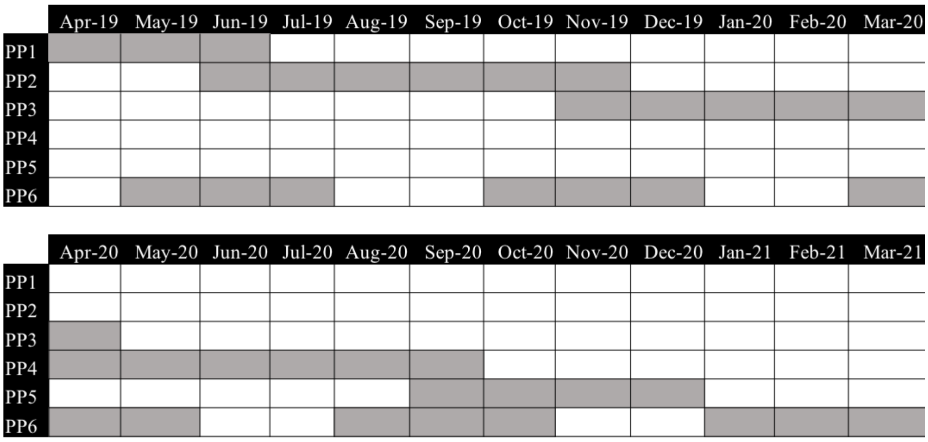

Fig. 1: A-CPS time plan for the different PPs

PP1 starts in April 2019 and has a duration of three months. PP2, PP3 and PP4 have a duration of six months each and start in June 2019, November 2019 and April 2020, respectively. PP5 starts in September 2020 and has a duration of four months. The dissemination activities in PP6 are carried out in correspondence of termination of the previous PPs while the evaluation activities in PP6 start in January 2021 and have a duration of three months. We are not planning to run more than two technical PPs in parallel.

3.4 Research Methodology

A-CPS employs a research methodology being an adaptation of the model for technology transfer described in [7]. The key features of this methodology are a tight collaboration between industry and academia and a three-step validation process ensuring that the research results will have both academic and industrial relevance. The research methodology starts with the definition of the project research goal and related challenges. For each challenge, one (or a set of) candidate solution(s) will be identified. Each solution will be validated from the research leader using use cases. Based on the results of the first validation step, the candidate solution will be further validated in dedicated workshops with the industrial experts, first, and on industrial use cases, later.

3.5 Expected Outcomes

In A-CPS, we target i) the extensions of existing vehicular-specific modelling languages, ii) the definition of automatic mechanisms enabling simulation- and analysis-based assessment of timing as well as back-propagation and exploitation of the observed results. We plan to disseminate the A-CPS results through 1 journal paper, 3 conference papers, 1 work-in-progress paper, 1 technical report and 5 case study demonstrators. A-CPS will provide Dr. Alessio Bucaioni with the opportunity to develop into an independent researcher in the area of model-driven engineering for cyber physical systems. A-CPS will help MDH in enhancing its competences in the domain of model-based engineering of embedded systems thus in strengthening its position as a leading research environment in such a domain. This project will provide AS with an opportunity to extend its commercial tools suite by supporting the modelling, analysis and simulation for parallel heterogeneous platforms (currently missing) to keep up with the pace of customers' technology shifts. A-CPS will provide VGTT with a unique possibility to shape the future of their current software development solutions by participating directly to their enhancement for upcoming technology shifts such as autonomous vehicles based on parallel heterogeneous platforms.

4 State of the Art

In the last decades, a plethora of domain-specific modelling languages and model-based methodologies have been proposed for the software development of vehicular embedded systems for single-core. EAST-ADL, AUTOSAR and RCM are just some examples, if we consider the automotive domain. Recently these languages have been provided with limited support for multicore [10] [4], but they have not been provided with support for heterogeneous platforms. There are a number of AUTOSAR-based frameworks for the specification of timing-analysis as [15] [6]. However, because AUTOSAR does not differentiate between the control and the data flows at the application software level, these frameworks can not provide precise timing analysis at early stages of the development. Moreover, they can not be employed for heterogeneous platforms. Based on RCM, the work on [12] leverages high-precision timing analysis at system level for homogeneous platform. However, the approach is fully manual. Given the ubiquity of software, there exists a corpus of literature devoted to the design of embedded systems and posing a special focus to timing requirements. In this respect, several works are based on the use of general-purpose languages such as UML as alternatives to domain-specific languages. GASPARD is a UML-based framework for the design of parallel embedded systems [5]. It prescribes a workflow made-up of subsequent analyses and refinement steps, from higher to lower abstraction levels. GASPARD does not support heterogeneity and focus on complementary non functional properties than timing. In recent years, several approaches dealing with CPS development by adopting multi-paradigm modelling techniques and leveraging simulation mechanisms to perform early analysis of systems have been proposed [9] [11]. However, they do not address parallelism nor heterogeneity. There are several ongoing Swedish and European research projects complementary to A-CPS. PreView[2] aimed at developing predictable software for multi-core

[2] `http://www.es.mdh.se/projects/442-PreView`

embedded systems. However, no focus is put on heterogeneous platforms, automation and combining model-based simulation and timing analysis. DPAC[3] aims at providing dependable platforms for computer-controlled functionality in autonomous systems. It targets software development and execution of embedded systems, but its main focus is dependability. Moreover, there is no explicit focus on heterogeneous platforms.

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