INTO-CPS PROJECT FACTS

Title:
Integrated Tool Chain for Model-based Design of Cyber-Physical Systems

Project Partners:
Aarhus University, Denmark
Newcastle University, UK
University of York, UK
Linköping University, Sweden
Verified Systems International, Germany
Controllab Products, Netherlands
ClearSy, France
TWT GmbH - Science & Innovation, Germany
Agro Intelligence, Denmark
United Technologies, Ireland
Softeam, France

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Project Website: www.into-cps.au.dk

Duration: 36 months (2015-2017)

What is INTO-CPS

Systems composed of closely coupled computing and physical elements are increasingly important in the modern world. Such Cyber-Physical Systems (CPSs) are characterised by a complex architecture and a design process involving different science and engineering disciplines. At the interface between disciplines, different formalisms and technical cultures meet, and the traditional approaches for designing systems vary significantly among the relevant fields. The developer of a CPS faces a large design space that is difficult to cover with hardware prototypes due to the high cost of their implementation. A common workflow for the model-based design of CPS – and the necessary tools – is currently missing.

To address these challenges, INTO-CPS seeks to create an integrated "tool chain" for comprehensive model-based design of CPSs. The tool chain will support multidisciplinary, collaborative modelling of CPSs from requirements, through simulation of multiple heterogeneous models that represent the physical elements as well as the computational parts of the system, down to realisation in hardware and software, enabling traceability at all stages of the development.

Project progress: SysML profile for INTO-CPS

To model complex systems, such as Cyber-Physical Systems, the Systems Modelling Language (SysML) offers a flexible framework. The Modelio tool, which is available as Open Source software, uses SysML to model a broad array of systems.

In INTO-CPS, a profile for SysML is being developed, which is specifically suited to model CPS, and connects the high-level modelling in Modelio to other modelling tools (20-sim, Overture, OpenModelica), the Co-Simulation Orchestration Engine and RT Tester for Test Automation.

The INTO-CPS profile currently specialises two SysML diagrams in order to support CPS modelling: the Architecture Structure Diagrams (ASDs) specialise the SysML Block Definition Diagrams (BDDs). ASDs allow modelling of the overall structure of the system by dividing it into "physical", "cyber" or "subsystem" blocks. Blocks are

mainly characterised by variables and ports. When a block is fully described, a FMI model description, containing its interfaces, can be exported and used in the other modelling tools. This export and import of the model description further connects the single tools in a workflow.

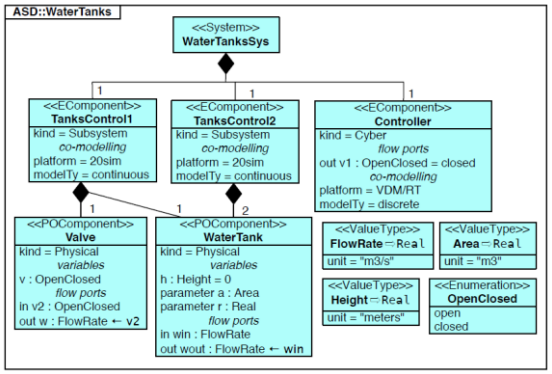

Figure 1: Architectural Structure Diagram in SysML

Connection Diagrams (CDs) specialise the Internal Block Diagrams (IBDs) of SysML, and describe the connections of ports between different block instances.

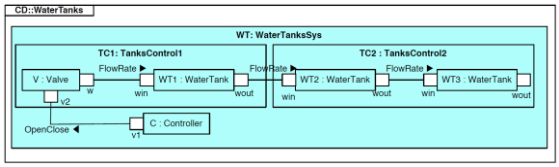

Figure 2: Connections Diagram in SysML

Based on the CD, configurations for the Co-Simulation can be exported since each model can be assigned to an FMU.

The latest version (1.0.30) of the Modelio profile can be downloaded free of charge at:

http://forge.modelio.org/attachments/download/16417/INTOCPS_1.0.30.jmdac

In addition to this implementation, the semantics for the INTO-CPS profile are being formalised. They will be published in the next months, and the publication will also be announced in one of the next issues of this newsletter.

Spotlight on a Case study: Building automation

Currently, buildings are responsible for 40 per cent of the energy consumption and 36 per cent of EU's CO_2 emissions[1]. Therefore, high energy efficiency of building infrastructures can be a key contributor to sustainability and for reducing the environmental impact of ITC installations. In this context, significant energy savings can be achieved using effective strategies like user profiling based on data gathered utilising Internet of Things (IoT) technologies to control equipment distributed in a building. For example, peak shaving strategies can yield savings in the infrastructure required to provide peak power and improved reliability of energy supply.

Within the INTO-CPS platform, we aim to integrate the outcome of each domain specific tool in the form of black-box modelling - Functional Mock-up Interface (FMI). We apply a CPS model-based design approach supported by the INTO-CPS platform for the evaluation of the Heating Ventilation and Air Conditioning (HVAC) system. By integrating discipline-specific models, e.g. software, thermal and electrical models, we gain greater confidence in the overall analysis and results.

[1] http://ec.europa.eu/research/industrial_technologies/eeb-challenges-ahead_en.html

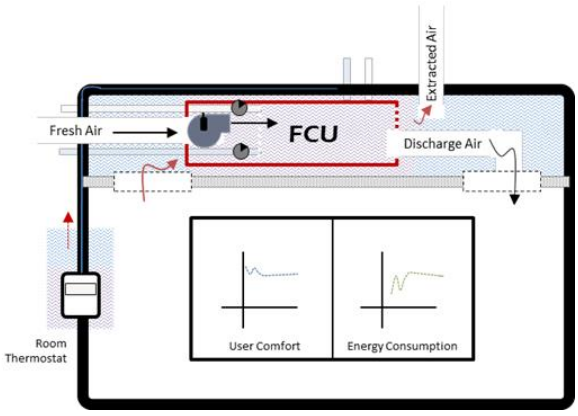

Figure 3: Fan Coil Unit Example for single-room air temperature control

We consider a single room control unit in order to assess the potential for co-modelling in this setting. We model a Fan Coil Unit (FCU) device as illustrated in Figure 1 that controls air temperature in a room through the utilisation of physical components and a software controller. Water is heated or cooled in a heat pump and flows into a Coil. A Fan blows air through the coil. The air is heated or cooled by the coil and flows into the room. A Controller can alter the fan speed and the rate of the water flow from the heat pump to the coil. The aim of the system is to maintain a fixed temperature in the room in which the FCU is located. The system level design of the case study is captured via SysML using the INTO-CPS extensions. The overall architecture of the system is realised as an INTO-CPS architecture diagram which is an extension of the SysML block definition diagram. We model control algorithms using the Overture tool and the thermal environment characteristics using 20 -sim and OpenModelica.

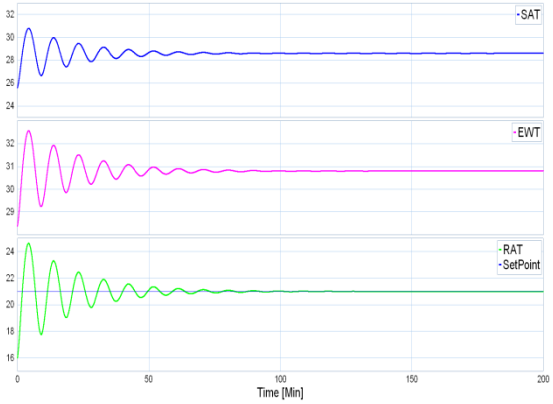

Figure 4: Co-simulation results of a single room with a 20-Sim model

The results shown in Figure 4 are for a heating mode simulation when the FCU is required to provide warm air to heat the room. As shown, there is a high correlation between EWT, SAT and RAT due to the thermal coupling between them. The PID controller tries to reduce the distance between RATsp and RAT by regulating EWT and SAT until the distance between them equals zero. The time required for RAT to reach RATsp is called settling time.

In our case, the PID controller requires a settling time of one hour to reach the set-point which is acceptable for the building automation case study. However, this settling time is part of a user comfort requirement and can be changed by retuning the PID parameters.

Call for challenges

As the INTO-CPS tools start forming a toolchain, much work has already been done to lay the foundations, we would like to invite the members of the Industrial Follower Group (IFG) to submit challenges for modelling. This will allow the companies providing the pilot studies to have access to the latest INTO-CPS tools and to have experts from academia and industry model their problems with state-of-the-art tools and methods.

These challenges should be a Cyber-Physical System from a real application that fits into the scope of INTO-CPS and that can be modelled with the INTO-CPS tools and methods.

The selected challenges will be, at least partially, made public as a showcase for the INTO-CPS technologies.

For more information on the challenges, please contact Ken Pierce or Carl Gamble from the University of Newcastle (kenneth.pierce@newcastle.ac.uk and carl.gamble@newcastle.ac.uk).

IFG webinar and workshop

To demonstrate the capabilities of the INTO-CPS tools, we are planning several webinars and workshops in 2016.

The first webinar, focused on the automotive industry, took place on Friday 22 April 2016 at 10 am (CET). There was a presentation of the status of INTO-CPS and demonstrations of how to use the tools for different tasks in the development of automotive CPS, as well as a Q&A session. More webinars will take place later in 2016 focusing on areas such as aerospace, railways and building automation.

On 14 June 2016, there will be a **face-to-face workshop in Linköping** (Sweden). It will be held in conjunction with the INTO-CPS plenary meeting so IFG members from the region have the opportunity to talk to the INTO-CPS developers and experience the tools first-hand. So, we would be happy to welcome you in Linköping on this date. The agenda is:

14:00 – 14:30	INTO-CPS Overview, status outlook
14:30 – 15:00	Tools (Overture, 20-Sim, OpenModelica, RT Tester, Modelio, COE)
15:00 – 15:15	Coffee break
15:15 – 16:30	Live demonstration & Hands-on testing
16:30 – 17:00	Questions & Answers

You can find more information on our website:

http://into-cps.au.dk/currently/events/show/artikel/seminar-for-the-into-cps-industry-follower-group/

If you are interested in any of these events, please send an e-mail to Peter Gorm Larsen (pgl@eng.au.dk) or Christian König (christian.koenig@twt-gmbh.de).

Upcoming events

The Building Automation case study will be presented at the INCOSE international symposium in Edinburgh (UK) on July 19th, 2016

INTO-CPS will be presented at the third International Workshop on Challenges and new Approaches for Dependable and Cyper-Physical Systems Engineering (De-CPS 2016) in Pisa (Italy) on June 17th, 2016.

For more updates, visit our website:

http://into-cps.au.dk/

and follow us on Twitter (@IntoCPS):

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