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

Project Coordinator:
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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: Traceability

During the development of Cyber-Physical Systems, different people (e.g. systems engineers, development engineers, test engineers) create many artefacts of different types, such as requirements, models or simulation results are created, often in many versions.

One of the goals of INTO-CPS is to provide tools for keeping track of this complexity, by means of traceability. For this purpose, a traceability architecture was designed, so that all the tools in the INTO-CPS tool-chain can send information about relevant events (e.g. creation of a model, execution of a simulation run) to a central database

The messages are following the standards OSLC (Open Services for Lifecycle Collaboration[1]) and Prov-N[2]. A schema was developed for the traceability messages, to make sure that they are all written in the same format. This schema, together with the use of standardized specifications and formats, allows other tool vendors to easily integrate their tools in the traceability environment of INTO-CPS. These specifications are described in the deliverables, which will be available on the project website soon.

The tools all send the traceability messages in the JSON format to a "daemon", which is integrated into the INTO-CPS application. This daemon then performs a check if the message format conforms to the schema. If that check is passed, the message is written into the database. This is schematically shown in Figure 1.

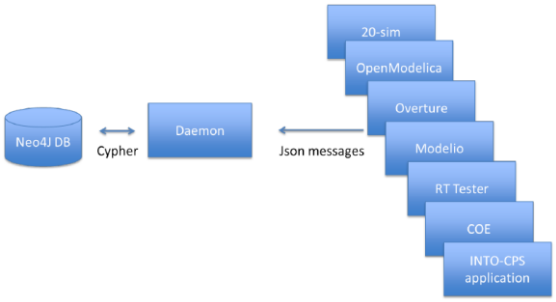

Figure 1: Schematic architecture of traceability

The benefit for the user is the ability to query the database for relevant relations. For example, the user can see all the FMUs in the project, and the requirements related to each FMU. Moreover, the user can find out which simulation results were generated from which FMUs and their version. More queries are being implemented in the remainder of INTO-CPS project. This part of traceability is integrated into the INTO-CPS application, which is shown in Figure 2.

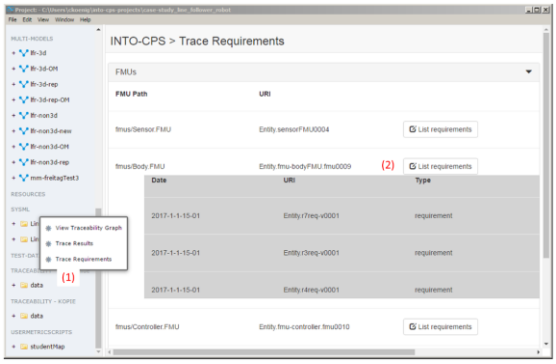

Figure 2: Integration of traceability in the INTO-CPS application.

Project progress: Hardware-in-the-Loop simulation with 20-sim4C

One of the goals of INTO-CPS is to develop code for real hardware, that can be tested with a simulated environment in a Hardware-in-the-loop scenario. To achieve this, Controllab has extended its 20-sim4C software (http://www.20sim4c.com/) with the ability to import source-code FMUs, which can be run on real hardware. Here, RaspberryPi 3 boards were selected as a target.

In a next step, the FMU running on the hardware can be connected to the INTO-CPS application through an FMI wrapper. A screenshot of the 20-sim4C user interface, with a simulation

[1] http://open-services.net/
[2] https://www.w3.org/TR/prov-n/

running on a Raspberry Pi 3, is shown in Figure 3 below.

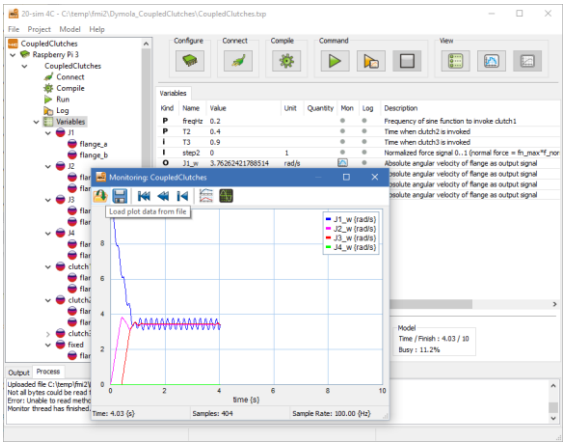

Figure 3: The 20-sim4C user interface with a simulation running.

This development allows the users to easily move from a Model-in-the-Loop scenario, where a controller is developed in 20-sim, or another compliant tool, to a Hardware-in-the-Loop setting. Thereby, the model-based design is realized, all the way from abstract system modelling in SysML, through modelling and virtual testing, down to code running on hardware.

Final Plenary meeting

On November 15th and 16th 2017, the final plenary meeting of the INTO-CPS took place in Aarhus (Denmark). This meeting marked the end of a successful 3 year project. In all work packages of the project, the goals were fulfilled, from developing a semantic basis, through technical developments of the tools, their evaluation in industrial case studies to development of guidelines for using the tools and methods.

One day before the final plenary meeting, a physical workshop was held with local IFG members, where the case studies were presented, and a study from an IFG member that used the INTO-CPS technologies. Additionally, the 3D animation features and their integration with virtual reality googles were demonstrated live. Figure 4 shows a photograph of the auditorium at this workshop.

Figure 4: The audience at the physical IFG workshop on November 14th in Aarhus.

The INTO-CPS Association

To continue the successful work that was carried out in INTO-CPS, an association as formed to own, maintain and further develop those results that form the core of the INTO-CPS tool-chain. These are the INTO-CPS Application (the user front-end), the Co-Simulation Orchestration Engine, the SysML profile, Design Space Exploration tools, traceability features (see above) and the 3D animation FMU.

At the kick-off meeting of the Association, the following board was elected:

Prof. Peter Gorm Larsen (Aarhus University), Ole Green (Agro Intelligence), Prof. John Fitzgerald (University of Newcastle), Jörg Brauer (Verified Systems).

Membership in the association brings several advantages, and is open to everyone. If you are interested in joining the association, please take a look at the website

http://www.into-cps.org

or contact Prof. Larsen (pgl@eng.au.dk).

Recent publications

On September 5th 2017, the first Workshop on Formal Co-Simulation of Cyber-Physical Systems was organized as a satellite event of SEFM2017 in Trento (Italy). This workshop was co-organized by Prof. Peter Gorm Larsen of Aarhus University and several members of the INTO-CPS consortium published their work there.

The program, including full text of the published papers, can be found on the workshop's website:

https://sites.google.com/view/cosimcps17

On September 15th 2017, the 15th Overture Workshop was held at Newcastle (United Kingdom). The workshop as co-organized by Prof. John Fitzgerald of Newcastle University. Some of the work of INTO-CPS was also presented at this workshop. The slides, and the final papers, can be found on the workshop's website:

http://overturetool.org/workshops/15th-Overture-Workshop.html

In addition, the following papers were published recently:

B. Thiele et al, *Towards a Standard-conform, Platform-generic and Feature-rich Modelica Device Drivers Library*, Proceedings of the 12th intl. Modelica Conference

http://www.ep.liu.se/ecp/article.asp?issue=132%26article=78

J. Fitzgerald et al, *Exploring the Cyber-Physical Design Space*, INCOSE International Symposium on Systems Engineering, Vol 27(1), pp. 371-385

http://onlinelibrary.wiley.com/doi/10.1002/j.2334-5837.2017.00366.x/abstract

For more updates, visit the project website:

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

visit our YouTube channel:

https://www.youtube.com/channel/UCHfzhFYht6sKiqarjqbmtaQ

and follow us on Twitter (@IntoCPS):

https://twitter.com/IntoCps