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:
Prof. Peter Gorm Larsen
Aarhus University
Email: pgl@eng.au.dk

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: Design space exploration

In the process of developing complex systems, such as Cyber-Physical Systems, many design decisions must be made. Some of the parameters are hard to determine initially, and experimental tests may not yet be possible in an early design phase. To speed up this process, Design Space Exploration (DSE) is a suitable method for optimizing system behaviour based on simulations.

We developed methods for DSE that allow optimization of design parameters to reach desired system behaviour. This comprises as a first step the definition of the variable parameters and their bounds and determination of the target values that should be optimized. In the next step, one of multiple available algorithms for sweeping the parameter space can be selected. Finally, the Co-simulation is initialized and the simulation runs start. Finally the results are presented in a meaningful way. In addition to single parameters, alternative designs that consist of different system parts can also be compared.

In the context of INTO-CPS, DSE has multiple connections. On the SysML level, different diagrams have been designed to derive the DSE parameters and target values from the existing system model. These diagrams were implemented in Modelio (see newsletter #3 for a description of the Architecture and Connections diagrams in Modelio).

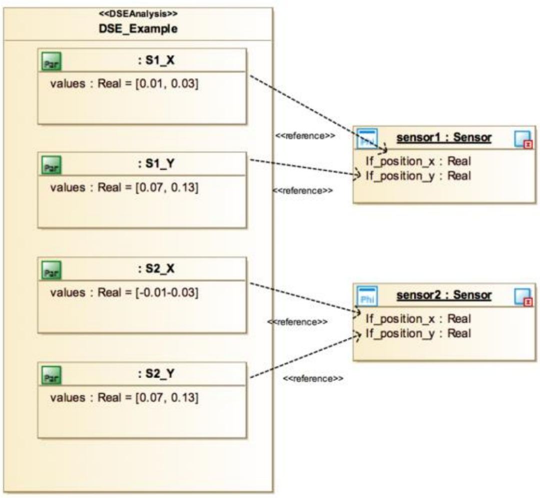

Figure 1: A DSE Parameter Connection Diagram in SysML

Figure 1 shows an example of the DSE Parameter Connection Diagram in SysML, where the SysML elements (the sensors and their position) are related with boundary values for a DSE analysis.

The algorithms have been implemented into the INTO-CPS application (see newsletter #4 for information on the application) to give the user a coherent and easy-to-use interface. Figure 2 shows how a DSE analysis can be configured and launched from within the INTO-CPS application.

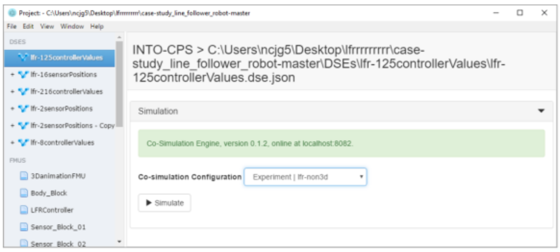

Figure 2: Integration of DSE in the INTO-CPS application.

The results from such a DSE analysis can then be shown in a web browser, e.g. as a Pareto front that shows the best trade-off between two goals (see Figure 3). This can help the designers in optimizing the system behaviour already in a rather early design phase.

Finally, methods to execute the DSE runs on a cloud are being investigated to allow users with limited computing power to benefit from DSE too.

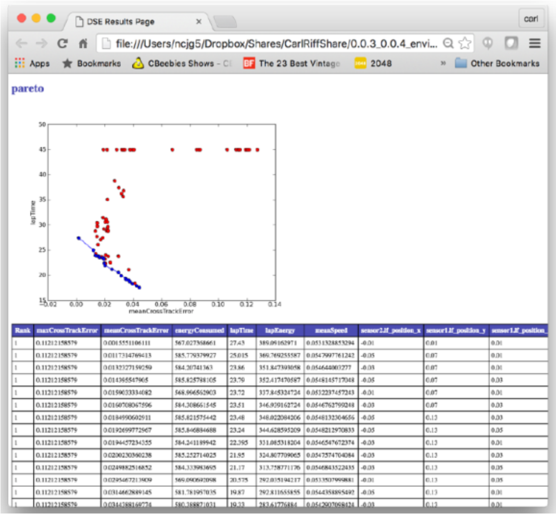

Figure 3: Results presentation from a DSE analysis

Project progress: Model checking

In the design process of CPSs, engineers need to make sure that the actual system behaviour is fulfilling the requirements. One approach to do so is Model Checking, where the system under test is exhaustively checked against certain requirements. These requirements must be defined in a logical formalism. Here, Linear Temporal Logic (LTL) has been chosen to define the requirements. The model that is being checked can either be a discrete event (DE) model, or a continuous time (CT) model.

Model checking is using the RT Tester tool-suite from Verified Systems (see also Newsletter #1). Using the model checking capabilities is integrated in the INTO-CPS application (see Figure 4) to give the user a coherent workflow and interface.

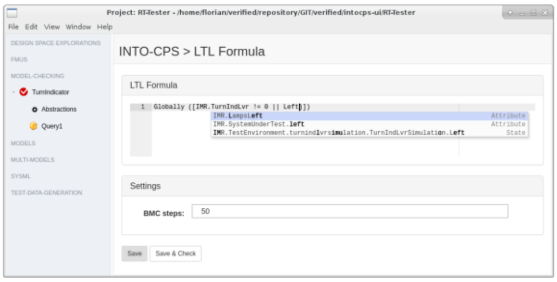

Figure 4: Writing requirements in LTL in the INTO-CPS application.

The model checker then examines the system under test in a limited number of steps. If no example can be found within the defined number of steps that contradicts the requirements, the example has passed the check. Otherwise, the model checker returns a counterexample. This helps the engineers validating the desired system behaviour.

Overhauled website

To give users and interested parties easy access to the desired information, we have overhauled the INTO-CPS website. The start page now lets you select the Industry section with application-oriented information and the Academia section with more in-depth background knowledge. Please check out the website at:

http://into-cps.au.dk

Upcoming events

IFG physical workshop: In conjunction with the final project meeting of INTO-

CPS, there will be a face-to-face workshop in Aarhus (Denmark) on November 14th, 2017.

If you are interested in this workshop, please contact Christian König (christian.koenig@twt-gmbh.de) or Peter Gorm Larsen (pgl@eng.au.dk).

Recent publications

M. Hasanagic et al, *Formalising and validating interface description in the FMI standard*, Intl. Symposium on Formal Methods.

http://dx.doi.org/10.1007/978-3-319-48989-6_21

S. Foster & J. Woodcock, *Towards Verification of Cyber-Physical Systems with UTP and Isabelle/HOL*, Lecture Notes in Computer Science

http://dx.doi.org/10.1007/978-3-319-51046-0_3

A. Mengist et al, *Traceability support in OpenModelica using Open Services for Lifecycle Collaboration (OSLC)*, Proceedings of the 12th international Modelica Conference

https://modelica.org/events/modelica2017/proceedings/ProceedingsOfThe12thInternationalModelicaConference.pdf

C. Gomes et al, *Co-Simulation state of the art*, Technical Report

https://arxiv.org/abs/1702.00686

For more updates, visit our 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