ITEA 3

Project Results

OpenCPS

New opportunities for high-quality systems modelling & simulation

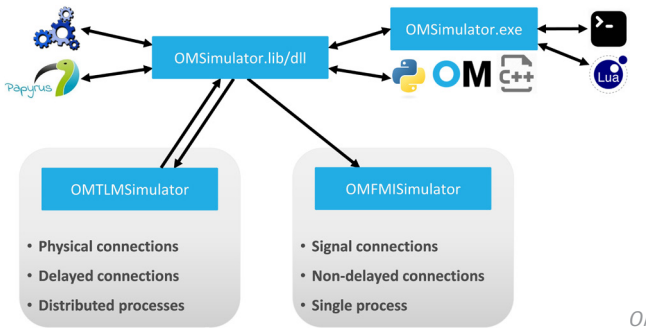
EXECUTIVE SUMMARY

The ITEA OpenCPS project focused on the development of standards and open-source solutions for the integration of models from various engineering disciplines, enabling collaborative, model-based Cyber-Physical Systems development. A major project outcome is an open-source, industry-grade master simulation tool for standardised model integration and numerically-robust distributed simulation.

PROJECT ORIGINS

Cyber-Physical Systems (CPS), containing integrated software, hardware and communication components that interact with physical and social environments, are developing very fast. Internet of Things (IoT), for instance, requires interoperability between numerous apps and devices. CPS providers therefore face an increasing demand for reliability, usability and flexibility. Industry competitiveness relies on cost-effectiveness, lead times and development eco-systems, yet some products are simply too dangerous or costly to validate with a physical prototype. One solution is to enable effective modelling and simulation of CPS throughout the entire value chain and system lifecycle. When based on open standards and open-source tools, this allows for greater control, increased cooperation and shared access to knowledge between organisations.

OpenCPS (Open Cyber-Physical System Model-Driven Certified Development) combined Unified Modelling Language (UML), Functional Mock-up Interface (FMI) and Modelica into an industry-grade, open-source model integration and co-simulation tool: OMSimulator. A unique feature is the combination of open standards FMI and System Structure and Parameterisation (SSP) with the Transmission Line Method (TLM) – a well-established technique for numerically-stable distributed simulation. The open-source approach lets end-users control and add features, allowing new users (including SMEs) to more easily access the market. OpenCPS also developed methodology and prototype tool support for roundtrip engineering between the system architecture and system simulation domains. The consortium used OMSimulator to develop demonstrators in various fields, including energy and infrastructure.



OMSimulator

TECHNOLOGY APPLIED

OpenModelica and Papyrus, as the leading open-source tools in the Modelica and UML/SysML domains, were significantly developed through OpenCPS. The joint project effort to develop OMSimulator played a key role in this. The master simulation tool is an engine for the creation of FMI- and SSP-based composite models, parameterisation, simulation and optimisation. It is integrated with graphical support in OpenModelica and Papyrus and is also available as a standalone C++ library with Python and Lua bindings, leaving it open for integration into scripting frameworks, third-party tools and specialised applications such as flight simulators or optimisation tasks.

Distributed simulation utilises TLM and techniques for the automatic coarse-grained/fine-grained parallelisation of whole FMI composite models and/or individual Functional Mock-up Units (FMUs). OpenCPS also integrated debugging and validation support for advanced state machines and complimentary real-time systems modelling paradigms. Prototype support exists for the modelling of requirements and generation of FMUs with code for embedded systems. These FMUs can be run in a real-time, interactive simulation to debug them, supported in a limited form for connected black-box FMUs, or in full if the model source code is available.

OpenCPS increases both the pace and efficiency of frontloading by enabling largescale simulation. This can range from tool support for large equation systems with a vast number of parameters and variables to model and information exchanges between large organisations with many engineering disciplines and specialised tools.

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MAKING THE DIFFERENCE

As these developments were led by an integrated project team of key developers and end-users, the project addresses the real-world requirements of companies of all sizes and domains. Although unable to afford existing intellectual property, smaller companies can enter the world of modelling using this open-source alternative, allowing for faster lead times, easier maintenance and new business models. For larger companies that see the benefit of collaboration, OpenCPS is a means of sharing knowledge and avoiding tool vendor lock-in. Saab, for instance, predicts a 15% drop in the development costs of Aircraft Vehicle Subsystems due to improved front loading capabilities.

To ensure industrial relevancy and encourage potential users, the consortium developed demonstrators in fields as diverse as aeronautics, naval and automotive. Using the FMI standard as a basis, some demonstrators served as collaboration platforms between companies. One example is the work of Siemens, EDF, EQUA and KTH on a Cycle Power Plant demonstrator. EDF's involvement allowed them to reuse their power plant models for Uncertainty Quantification, resulting in a 100% reduction in model development costs. EQUA, meanwhile, saw a market share increase of EUR 35 million in the Nordic and DACH regions. Siemens estimates a 5% yearly cost reduction in predictive maintenance and a 10% increase per year in power systems using gas turbines for balancing. In terms of societal impact, Siemens also sees potential to reduce CO2 emissions from gas turbines.

Regarding automotive vehicle energy management, Sherpa Engineering identified a new business activity called Simulation Architect, worth roughly EUR 500 thousand per year in the initial phase, plus a EUR 400 thousand contribution to their Vehicle Energy Management Platform for 2019. ESI estimates a EUR 6 million increase in their Advanced Driver Assistance Systems market share and SIRHENA predicts a 25% cost reduction in control system development for ship, submarine and UUV applications.

Due to the fast-growing nature of CPS and OpenCPS's ongoing standardisation efforts, the number of domains that can make use of early or largescale modelling and simulation will continue to rise. Increased access to the best tools can only lead to greater opportunities for both collaboration and competition.

MAJOR PROJECT OUTCOMES

Dissemination

- More than 70 documented papers, presentations at conferences and workshops

Exploitation (so far)

New products:

- OMSimulator: Industry-grade and open-source model integration and co-simulation tool
- PhiSystem simulation module
- txtUML: Generation of UML2 model from textual models
- SSP-FMU design extension for Papyrus supporting round-trip engineering

New services:

- xtUML-Wrapper for FMI: Enables integration of any xtUML-model with a simulation infrastructure supporting FMI 2.0
- FMI Export module in Pro-SiVIC
- Papyrus support of OMG Precise Semantics for State Machine (PSSM) standard
- Multi-Domain Modelica Models: Enabling Gas Turbine and Power Grid Analysis

New systems:

- Digital Twin: OMSimulator utilised in an FMI-based digital twin for automated flight test evaluation and model validation
- IDA Software-in-the-Loop (SiL) simulator for PLC code

Standardisation

- FMI: Contributions on improved support for discrete-time systems and TLM co-simulation. Change Proposal submitted by OpenCPS now under implementation for FMI3.0. called "Intermediate Variable Access" enabling a wide range of advanced co-simulation techniques
- SSP: Coordination with, testing, and review of SSP development towards SSP v1.0 released in March 2019
- OMG: Proposal on UML state-machine execution semantics accepted during the project

ITEA is a transnational and industry-driven R&D&I programme in the domain of software innovation. ITEA is a EUREKA Cluster programme, enabling a global and knowledgeable community of large industry, SMEs, start-ups, academia and customer organisations, to collaborate in funded projects that turn innovative ideas into new businesses, jobs, economic growth and benefits for society.

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KTH - Royal Institute of Technology
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RISE - Research Institute of Sweden
Saab AB
Siemens Industrial Turbomachinery AB

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December 2015

Project end
April 2019

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