ITEA4

Project Results

EMBrACE

A virtuous circle in large-scale system design

Thanks to ITEA's international, practice-oriented structure and funding, EMBrACE (Environment for model-based rigorous adaptive co-design and operation of CPS) has developed a Common Requirement Modelling Language (CRML) and methodology for easier collaboration between stakeholders in large-scale cyber-physical system (CPS) design.

In current complex system design, one team typically expresses requirements and separate teams attempt to meet these at different development stages. However, as systems get larger and become more dynamic thanks to the Internet of Things (IoT) and CPS grow more diverse in both hardware and software, it becomes harder to express and check these requirements, especially in relation to sustainability or safety/security goals. Prior to EMBrACE, no standard existed to address these concerns.

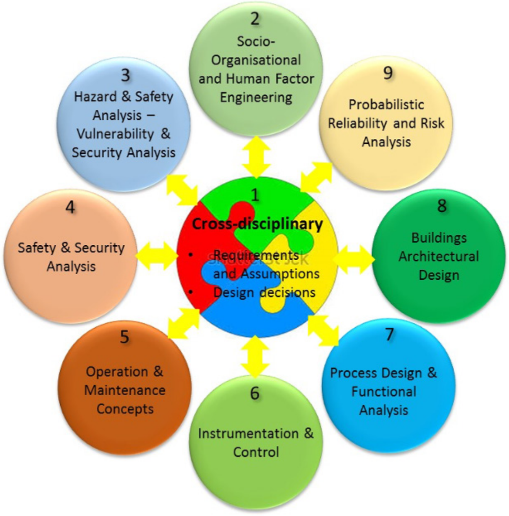
The project has generated four key innovations for large-scale system design. Firstly, the CRML specification serves as a new requirement and architecture modelling standard for system modelling, enabling the composition of models of different origins. This will allow stakeholders to understand requirements and perform analysis, verification, validation and simulation from the early design stages. Alongside this, a model-based methodology for complex CPS and IoT engineering covers all development phases from preliminary studies to operation, preventing costly last-minute modifications. These results are supplemented by tool support for very large systems, including variant handling, and tool support and coupling to the CRML for contract-based design. Overall, this will make requirements easily understandable across domains and align them with real-world constraints and uncertainties.

Technology applied

EMBrACE's CRML allows for the expression of a model's constraints and requirements at a higher level, including which parts of an architecture can be represented and connected at different levels of abstraction. This could be, for example, a more general architecture alongside different behavioural models for sub-models that should be run within certain test parameters. This enables CPS development through modelling and simulation. In tandem with the accompanying methodology, it allows requirements to be specified for multiple stakeholders, who can collaborate and simulate the overview of requirements alongside the system to ensure that the requirements are fulfilled.

EMBrACE's other group of innovations relates to extending simulation tools to reach the necessary capabilities for this type of large-scale simulation with different stakeholders and models. For instance, the CRML Compiler tool transforms CRML models into Modelica models so that requirement models can be simulated alongside physical models. A particular achievement was the seamless integration of the CRML with SysML, making it easier to interconnect the project's results to existing frameworks.

These results have also been demonstrated in four domains. For the cooling sub-systems of nuclear energy plants, EDF was able to define safety requirements and developed a model of the sub-system for this. In aerospace, Saab worked on how to express the requirements of a flight simulator in order to validate the test suite that will be used to ensure that the simulator has been tested completely. Using heating and ventilation systems for buildings, Swegon demonstrated that even very complex simulations can be decomposed into smaller models and still work as a whole. Finally, Siemens Energy made small changes at their gas turbine factory to examine how this affects supply meters and performance, including analysing different parts of a turbine in combination.



^ Engineering disciplines with different requirement on the system

Making the difference

From a technical perspective, EMBrACE offers various productivity improvements. In Swegon's buildings demonstrator, for example, automatic decoupling into nine cores offers a simulation time of 11.5 hours versus 64.9 hours for the full model, an almost sixfold decrease. Similarly, Saab's general framework for automated model validation and flight test evaluation improved the quality of model-based decisions and virtual testing, thereby reducing the number of design iterations by 30% and test rig development costs by 25%. The knock-on benefits include a 15% drop in the number of design iterations to achieve a working system and 35% fewer costs for model/simulator verification, validation and declaration.

The consortium is also using EMBrACE to expand their portfolios, with Knowledge Centric Solutions, EQUA, IncQuery Labs, Saab and Linköping University all releasing new (versions of) tools or ontologies with support for large-scale and/or requirement modelling technologies. Even SMEs can benefit from this: Modelon's Impact tool, for instance, enables parallel simulation methods for cloud-based multi-simulation and post-processing in the browser and will allow them to provide solutions to customers and industries that were previously unreachable. Such developments will enable the partners to expand their share in a collaborative product definition management market worth approximately USD 20 billion.

To secure long-term impact, the consortium is currently working on standardisation of the CRML, the specification of which has already been made open source to expand the project's reach. This will potentially include extensions to existing standards like Modelica and FMI. As EMBrACE's results are taken up, the consortium expects to see large sustainability improvements: a better understanding of the operating conditions and needs of systems allows for more efficient design and fewer tests, allowing companies to more actively contribute to solutions that reduce their carbon footprint. This will bring direct benefits to the companies, such as EDF's predicted 30% reduction in large project costs, making EMBrACE a virtuous circle for both business and society.

Major project outcomes

Dissemination

- Over 10 publications (Journal of Aerospace Information Systems, Modelica conference proceedings, Electronics)
- Internal dissemination presentations (Siemens, EDF) and presentations at conferences and workshops (MODPROD, Modelica Conference, WAFERS workshop, Modelica Association)

Exploitation (so far)

- RapidSSP 3rd party toolbox for automated extraction and expression of parameter values according to the SSP standard
- Embrace.ssp: captures industry grade requirements on simulator applications expressed through the FMI and SSP standards
- New version of IDA-ICE with Automatic parallelisation through decoupling of large scale models
- A new module with support for integration of external user interfaces through a modern web browser
- Implementation of SSP standard support in the Catia simulation tool
- The Simcenter Studio product now integrates a solution to visualise SysMLv2 models, in a system design context
- SSP support in Simcenter Studio
- Extension of Modelon Impact with parallel simulation methods for cloud-based multi-simulation and post-processing
- New versions of OpenModelica, OMSimulator including support for large-scale systems

Standardisation

- CRML specification released
- Presentations for standardisation organisms (SSP, SYSML design groups)

EMBrACE

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Partners

Belgium

- Siemens Industry Software NV

France

- Digital Product Solutions
- Electricité De France

Germany

- Bielefeld University of Applied Sciences

Hungary

- Budapest University of Technology and Economics
- IncQuery Labs cPlc

Spain

- Knowledge Centric Solutions

Sweden

- Equa Simulation AB
- Linköping University
- Modelon AB
- RISE - Research institutes of Sweden SICS East
- Saab AB
- Siemens Energy AB
- Swegon Group AB

Project start

November 2019

Project end

April 2023

Project leader

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Project website

https://itea4.org/project/embrace.html