EMPHYSIS

Bridging the gap between digital simulation and embedded software with eFMI®

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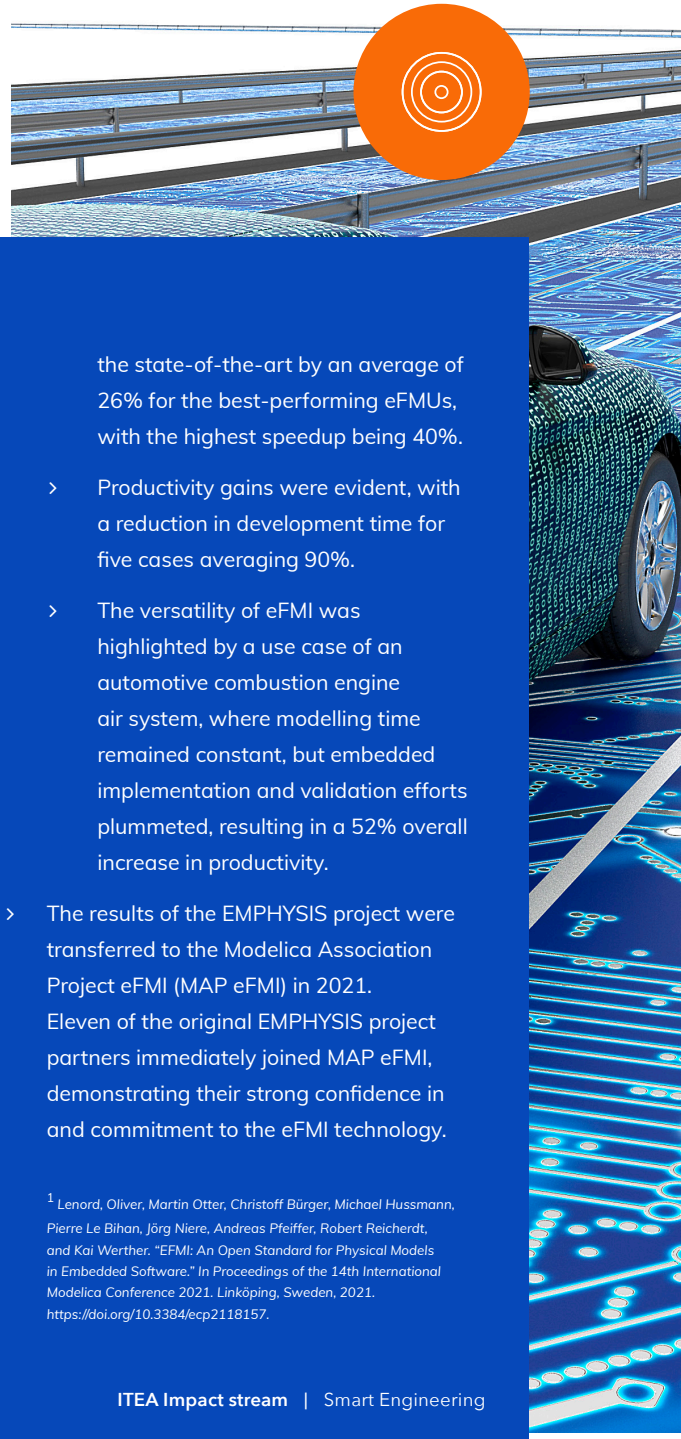

In the realm of developing new functionalities, engineers often discover that their profound understanding of the physics governing their products falls short when it comes to crafting functions for embedded targets. This is due to the demanding certification requirements of safety-critical software and the diversity in embedded ecosystems and their harsh resource restrictions on real-time timings, available computational power and memory. While this might result in a never-to-be-realised excellent initial idea of operating and controlling their product in a much smarter way, at the same time it reveals the need for a link between the digital simulation of real-world physics and embedded software leveraging on such physics models.

The ITEA project EMPHYSIS was set up to overcome this challenge. The project successfully ran from 2017 to 2021, uniting 26 partners from Belgium, Canada, France, Germany and Sweden. EMPHYSIS aimed to establish a new open standard laying the foundation to develop innovative tools, facilitating the realisation of model-based functions directly in embedded software with improved code efficiency.

Impact highlights

- The project carried forward the highly successful Functional Mock-up Interface (FMI®) standard for model exchange and simulation and developed a new standard, the Functional Mock-up Interface for embedded systems (eFMI®).
- eFMI reduces the time and risk to market of embedded control software for complex cyber-physical systems, increases collaboration and knowledge exchange between physics-based engineering and embedded software domains, and increases productivity.
- The intensive performance assessment conducted by BOSCH[1], to compare eFMI solutions with state-of-the-art handcrafted solutions for six representative application scenarios, showed promising results:
  - Four of the six benchmark cases surpassed the handcrafted solutions and the top eFMUs requiring 9% less data memory on the targeted BOSCH MDG1 multicore ECU.
  - Five benchmark cases excelled in ECU runtime performance, exceeding the state-of-the-art by an average of 26% for the best-performing eFMUs, with the highest speedup being 40%.
  - Productivity gains were evident, with a reduction in development time for five cases averaging 90%.
  - The versatility of eFMI was highlighted by a use case of an automotive combustion engine air system, where modelling time remained constant, but embedded implementation and validation efforts plummeted, resulting in a 52% overall increase in productivity.
- The results of the EMPHYSIS project were transferred to the Modelica Association Project eFMI (MAP eFMI) in 2021. Eleven of the original EMPHYSIS project partners immediately joined MAP eFMI, demonstrating their strong confidence in and commitment to the eFMI technology.

[1] *Lenord, Oliver, Martin Otter, Christoff Bürger, Michael Hussmann, Pierre Le Bihan, Jörg Niere, Andreas Pfeiffer, Robert Reicherdt, and Kai Werther. "EFMI: An Open Standard for Physical Models in Embedded Software." In Proceedings of the 14th International Modelica Conference 2021. Linköping, Sweden, 2021. https://doi.org/10.3384/ecp2118157.*

Project results

eFMI emerges as an open standard, offering a systematic approach to developing advanced control functions tailored for safety-critical and real-time targets. At its core, eFMI serves as a standardised workspace – a common ground – for information exchange and collaboration among stakeholders and their tooling, working on different abstraction levels and viewpoints of a common cyber-physical product. The eFMI workflow empowers developers to model systems at a higher level of abstraction, starting with a reusable, high-level, component-oriented and physics equation-based model. eFMI tools automatically transform this into a solution suited for embedded software, enabling a wide variety of advanced model-based approaches for control and diagnosis. The main benefits are:

- Overcoming vendor lock-in thanks to eFMI being an open standard.
- Accelerated development time and reduced costs thanks to automated toolchains.
- Enhanced utilisation of domain experts and their tooling by providing well-defined plug-in points for the physics modelling and embedded domains.
- Facilitating new ways for OEM-supplier collaborations with complementary viewpoints and respective toolsets along the eFMI workflow.

Exploitation

EMPHYSIS showcased its process through 11 industrial use-cases in the automotive domain, a Modelica open source library with 22 examples comprising about 40 real-time simulation configurations, and 13 tool prototypes supporting eFMI of which 6 have been commercially released in the meantime.
The indicators of conducted assessments are auspicious: eFMI reduces the time and risk to market of embedded control software for complex cyber-physical systems, increases collaboration and knowledge exchange between physics-based engineering and embedded software domains, and increases productivity. The virtual sensor industrial demonstrators are in particular disruptive technologies since such applications had not been considered affordable for physical systems of this level of complexity. The development effort and risk of errors in handwritten respective C production code solutions are unacceptable.

The results of the EMPHYSIS project were transferred to the Modelica Association Project eFMI (MAP eFMI - https://www.efmi-standard.org) in 2021 to prepare them for open access standardisation and publication, and the organisation of a volunteer community promoting and developing eFMI. In addition to the eleven original EMPHYSIS project partners who immediately joined MAP eFMI, the subsequent membership applications from Altair Engineering Inc., Institute of Vehicle Engineering CO. LTD, Mercedes-Benz AG, and Mitsubishi Electric Research Laboratories further underscore the project's broad relevance across diverse sectors.

A major milestone has been the provisioning of a complete eFMI toolchain backed by first commercial tool releases available on the market and covering the whole eFMI workflow from physics modelling in Modelica to production code on dedicated embedded platforms.

In essence, EMPHYSIS was a journey of innovation and collaboration that has paved the way for a transformative technology for embedded software, and MAP eFMI is set to carry the torch forward.

EMPHYSIS

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PROJECT LEADER

Oliver Lenord, Robert Bosch, Germany

PROJECT START

September 2017

PROJECT END

February 2021

PROJECT WEBSITE

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

PARTNERS

Belgium
- Dana Belgium ◉
- Siemens Industry Software ◉
- University of Antwerp NEXOR ◉

Canada
- Maplesoft ⊙

France
- CEA ○
- Dassault Systemes ◉
- FH Electronics ⊙
- Institut Polytechnique de Grenoble ◉
- OSE Engineering ⊙
- Renault ◉
- Siemens Industry Software ◉
- SOBEN ⊙

Germany
- AbsInt Angewandte Informatik ⊙
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- dSPACE ◉
- Elektronische Fahrwerksysteme ⊙
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- ETAS ◉
- PIKETEC ⊙
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Sweden
- Autoliv Sverige ◉
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- Linköping University ◉
- Modelon ⊙
- RISE - Research institutes of Sweden SICS East ○
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