



Project Results

EMPHYSIS

Rising to the automotive complexity challenge

EXECUTIVE SUMMARY

Through improved physical modelling and simulation tools in the design of advanced control and diagnosis functions, the ITEA project **EMPHYSIS** combines the productivity benefits of automation with the better real-time performance and memory consumption of embedded software in the automotive domain.

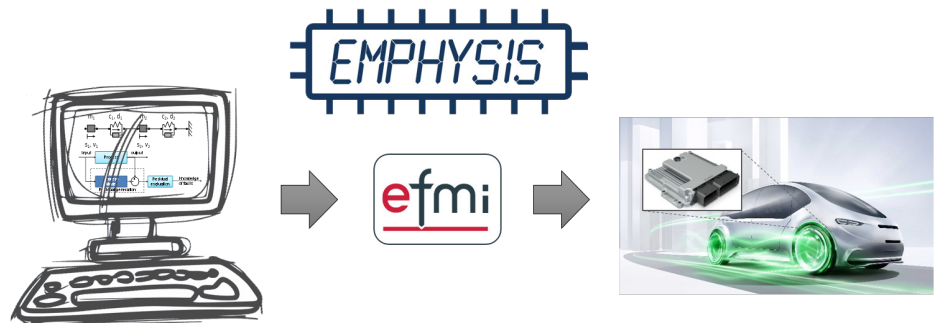
PROJECT ORIGINS

How can road vehicles be kept safe, clean and efficient despite increasing complexity in vehicle and infrastructure software and systems? Trends such as electrification and demands for advanced functionalities create a greater need to integrate physical models in embedded software. Currently, success depends on function developers who must be experts in physical modelling, control engineering, numerics and embedded software implementation according to strict regulations. Combined with technological limitations, this process is inefficient and relatively unscalable.

EMPHYSIS (EMbedded systems with PHYSical models In the production code Software) bridges the gap between diagram and equation-based physical modelling and highly efficient embedded code generation. Using advanced algorithms based on physical models, the project enhances the code production of embedded systems in vehicles, thereby improving the performance of underlying systems and increasing embedded software development productivity. By extending the successful FMI (Functional Mock-up Interface) standard to embedded systems, EMPHYSIS also provides an open alternative to propriety standards (helping to avoid vendor lock-in), plus numerous tools and multiple path proposal.

TECHNOLOGY APPLIED

As software systems grow larger and more complex, maintainability becomes a limiting factor for advanced control and diagnosis function



An open standard bridging the gap between the physical modeling & simulation domain and the embedded software world.

development, with function developers using cumbersome and error-prone manual workflows. Through its eFMI (Functional Mock-up Interface for embedded systems) standard, EMPHYSIS negates these limitations by allowing physical modelling and control engineering experts to collaborate effectively with embedded software developers using their preferred tools. The eFMI workflow is supported by three tool categories: modelling & simulation, embedded software and verification & validation. A set of reference cases supports the quality and reliability of the tool chain. An eFMI Compliance Checker was also developed to ensure the high quality of recent and future eFMI implementations.

The eFMI workflow allows developers to model a system on a higher level of abstraction, starting

with a reusable, high-level, component-oriented and physically-structured model. The tooling kit automatically transforms this into a solution which can be better integrated into embedded software, including the option to easily provide the same function in multiple variants based on different code generator and compiler configurations within the same eFMU (Functional Mock-up Unit for embedded systems). These variants could be optimised according to a desired trade-off between little memory or best run-time performance, as well as target-specific optimisation which is infeasible under manual conditions. Overall, automation improves speed, repeatability, scalability, reliability and cost-effectiveness. Traditionally, this would come with a trade-off, but EMPHYSIS has achieved them all simultaneously.

MAKING THE DIFFERENCE

Using an eFMI Performance Assessment demonstrator, EMPHYSIS' key technical outcomes have been illustrated in six component use-cases with negatively-defined KPIs: at most, a 25% reduction in run-time performance and 25% greater memory consumption versus state-of-the-art manual code (in exchange for the aforementioned automation benefits). Instead, four use-cases outperformed the manual code in either or both areas, with the top eFMU requiring 9% less data memory. For run-time performance, five use-cases exceeded the State-of-the-Art by an average of 26% for the best-performing eFMUs. The knock-on benefit for productivity saw a reduction in development time for five use-cases, including by 93% for a PID controller, 92% for a drive train controller and 88% for a slider crank controller. This also demonstrates eFMI's versatility: the air system use-case, for instance, required the same modelling time but saw a radical drop in embedded implementation and validation for a 52% overall increase in productivity.

A major proof of eFMI is a set of 11 demonstrators from multiple domains, including an advanced emergency braking system controller, powertrain vibration reduction and a transmission model as a virtual sensor. After running 402 analysis cases and 538 test scenarios, most of EMPHYSIS' 14

tools will mature these prototypes and provide open or commercial implementation on the market. For tool vendors, which are typically disconnected from the world of embedded systems, this will enable access to new markets and customers. The ECU (Electronic Control Unit) devices market, for example, was worth USD 33 billion worldwide in 2016 and is expected to grow by 6.8% annually up to 2025. For OEMs, issues with higher levels of complexity can now be addressed, enabling advanced functionalities at lower development and maintenance costs. An OEM Advisory Board has been established to gather additional requirements, input and use-cases and further disseminate the project's results, helping to secure uptake and future innovations in new domains.

Regarding the future, the eFMI Modelica Association Project (MAP) has now been established to continue EMPHYSIS' successes. For society as a whole, the software improvements from each project will translate into safer and more efficient vehicles which are able to keep pace with customer demands and help to tackle climate issues in the longer term. For now, however, the project's message is clear: by taking full advantage of an equation-based, component-oriented modelling language with a good library, 90% gains can be made in productivity without compromising on code quality.

MAJOR PROJECT OUTCOMES

Dissemination

- 42 journal and conference publications.
- Several presentations including an invited talk at the Modelica Jubilee Symposium 2019 and international conference, e.g., Modelica Conference '21, SIAT '21, IFAC '20, IEEE CDC '20, MoDeVva '20, ICSMM '20, EOOLT '19, SysTol '19, ICC '19, SpringSim '19.

Exploitation (so far)

Enhanced Products (eFMI supporting tools):

- Modeling & Simulation: Dassault Systèmes – Dymola, ESI ITI – SimulationX, Modelon – Modelon Impact, Siemens – Simcenter Amesim.
- Embedded code generating tools: dSPACE – TargetLink, ETAS – SCODE-CONGRA, Dassault Systèmes – AUTOSAR Builder, Siemens – CSD.
- Validation & Verification tools: AbsInt – Astrée, PikeTec – TPT, CEA – QuRTOS-DSE.

New Products: Dassault Systèmes – CATIA ESP (Embedded Software Producer).

New Open Source Projects (eFMI supporting tools and libraries):

- eFMI Compliance Checker.
- eFMI Container Manager.
- eFMI Test Cases Modelica library.
- eFMI Modelica support functions library.

Standardisation

- eFMI 1.0.0alpha4 released Feb. 2021.
- Modelica Association Project eFMI (MAP-efmi) founded March 2021.

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.

EMPHYSIS 15016

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Project start

September 2017

Project end

February 2021

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