The MegaM@Rt2 ECSEL Project

MegaModelling at Runtime – Scalable Model-based Framework for Continuous Development and Runtime Validation of Complex Systems

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Abstract. A major challenge for the European electronic components and systems (ECS) industry is to increase productivity and reduce costs while ensuring safety and quality. Model-Driven Engineering (MDE) principles have already shown valuable capabilities for the development of ECSs but still need to scale to support real-world scenarios implied by the full deployment and use of complex electronic systems, such as Cyber-Physical Systems, and real-time systems. Moreover, maintaining efficient traceability, integration and communication between fundamental stages of the development lifecycle (i.e., design time and runtime) is another challenge to the scalability of MDE tools and techniques. This paper presents "MegaModelling at runtime – Scalable model-based framework for continuous development and runtime validation of complex systems" (MegaM@Rt2), an ECSEL–JU project whose main goal is to address the above mentioned challenges. Driven by both large and small industrial enterprises, with the support of research partners and technology providers, MegaM@Rt2 aims to deliver a framework of tools and methods for: (*i*) system engineering/design and continuous development, (*ii*) related runtime analysis, and (*iii*) global model and traceability management.

Keywords: model-driven engineering; system design; runtime; megamodelling

1 Problem

In the global context, the European electronic industry faces stiff competition. Electronic systems are becoming more and more complex and software intensive [5], which calls for modern engineering practices to tackle advances in productivity and quality of these, now, cyber-physical and real-time systems [4]. In the last years, the ecosystem around MDE (Model-Driven Engineering) [2] has flourished, providing developers with a plethora of tools to support modelling tasks. However, these technologies need to be further developed to scale for real-world industrial applications as well as to provide advantages at runtime. The ultimate goal of increasing productivity and reducing costs while ensuring safety and quality in development, integration and maintenance, can be achieved by incorporating established practices that integrate design and runtime aspects [1] within systems engineering techniques and methods. Industrial-scale models, which are usually multi-disciplinary, collaborative, combine several product lines and include strong system quality requirements, can be exploited at runtime by means of advanced tracing and monitoring. This represents and opportunity for achieving a continuous systems engineering lifecycle including both design and runtime phases, ensuring the quality of the running system and getting valuable feedback to design phase [3]. This paper presents "MegaModelling at runtime – Scalable model-based framework for continuous development and runtime validation of complex systems" (MegaM@Rt2)[a], an ECSEL–JU project whose main goal is to address the above mentioned challenges.

2 Impact

The ECSEL Joint Undertaking[b] program seeks to invest in projects that strengthen the industrial competitiveness, enable economic growth and improve sustainability. Europe has a reasonably strong position in the world embedded market (30%), but this is falling as other geographies grow—some at the vanguard and others catching up. The MegaM@Rt2 consortium argues that investment in capability of the software development tools market, although only a fraction, has a very large pay-off. We have seen that the software component of the systems is growing increasingly in importance. As the hardware becomes commoditized, the added value will rapidly shift to the software. Achieving technological and competitive superiority in software development tools will allow European firms to participate with greater dominance in the overall software market.

Specifically, MegaM@Rt2 achieves this in part through reducing development and exploitation costs and in part by allowing mastery of more complex systems. Reducing development costs and time-to-market is a competitive advantage, allowing greater innovation in each product and faster reaction to hardware changes or new usage scenarios on the other. As the cyber-physical real-time systems evolve, the agility to react rapidly to new opportunities is a critical success factor for businesses. Mastering ever more complex systems allows new usage scenarios to emerge, based on optimization of greater problems or more optimized solutions for existing ones. Thus, improved software development will allow the bigger players to better position their overall solutions and engender small businesses fulfilling niche needs for high end bespoke software.

3 Solution and Approach

The MegaM@Rt2 Framework comprises several tool sets for holistic *systems engineering*, *model and traceability management*, and *runtime analysis*. Those tool sets are highly

[a] https://megamart2-ecsel.eu
[b] http://www.ecsel-ju.eu/web/index.php

interconnected to achieve the goal of linking large scale industrial system design models with runtime analysis results. *Systems engineering* deals with integrating the existing industrial practices, verification and validation on system level. *Runtime analysis* is conducted with monitoring, online testing and verification as well as models@run.time techniques. Design models, trace models and runtime models of the system are related by means of *model and traceability management*.

MegaM@Rt2 Systems Engineering approach integrates a variety of current engineering practices as required by the project industrial case studies. This is based, on a global system model providing a complete and holistic view of the system integrating heterogeneous artefacts (requirements specifications, design models, software components) produced by each of these practices. This model includes a precise specification of the desired functional and non-functional properties through standard modelling languages, such as UML, SysML and MARTE, as well as Domain-Specific Languages (DSLs) by means of UML Profiles. Additionally, the approach is based on a model verification that is decidable, automatic and not limited to a certain subset of model constructs. Eminent approaches and theories which are significant in analysis technologies are applied to further the accuracy and rapidity of verification, validation and testing activities.

MegaM@Rt2 Runtime Analysis approach seeks to obtain a successfully running application thanks to productive design models that are continuously refined with runtime feedback. Traditional methods for model validation and model-based testing (MBT) will have to be rethought and/or extended in order to fully tackle the specificities of runtime analysis. Online MBT will be supported, where the test generation and execution are realized simultaneously. As an extension of online MBT and runtime verification, model-based monitoring will allow to observe executions of the system (in its environment) and to compare them against the executions of a model. Monitoring will also allow the system to be stimulated by its environment and not only to observe that its execution conforms to the one specified by the model. Finally, monitoring will let us observe the system execution in its real environment and compare the performance against the expected attributes as defined at design-time.

MegaM@Rt2 Model and Traceability Management is a key ingredient of the framework as it is dedicated to support traceability across all layers of the system design and execution (runtime). This enables continuous integration practices at the systems engineering level. To make this possible, MegaM@Rt2 combines metamodelling and trace impact inference techniques. Relying on the unification power of models and model-based techniques, megamodelling (also called *global model management* or *modelling in the large*) provides efficient means of describing, handling and managing the many different heterogeneous artifacts implied by the large-scale industrial scenarios in MegaM@Rt2. Megamodelling will maintain traceability information between design and runtime in order to provide feedback to designers. Thus, we will develop a methodological loop between models at design time and runtime levels.

4 Results

The main expected result of MegaM@Rt2 is a practical framework incorporating methods and tools for continuous system engineering and validation. This framework is composed of three main tool sets for (*i*) system engineering/design & continuous development; (*ii*) related runtime analysis; and (*iii*) global model & traceability management. As a consequence, the project is organized around the research work and realization of these tool sets. Their integration and actual application onto a set of concrete use cases, covering different industrial domains, is also a central aspect of the project.

The work in MegaM@Rt2 follows an iterative and incremental approach divided into three consecutive phases. In the first phase we specify the requirements, validation scenarios, global architecture and roadmap. In addition, case study partners experiment with baseline technologies while technology providers develop the first set of prototypes. In the second phase, we will consolidate these prototypes, integrate them in a first release of the MegaM@Rt2 framework and run an initial set of validation scenarios. Based on the obtained results, in the third phase, we will integrate and validate the technical solutions, provide final validation and experience reports from the use cases (as well as a final management report).

MegaM@Rt2 is a three-years project starting in April 2017, and as of now – first quarter of 2018 – the project is in it first phase. Up to now, requirements have been extracted from the use cases (deliverable D1.1), by exploiting the collaboration among the use case providers – mainly large industrial companies – and the technical providers – composed of both service/product companies and experienced researchers from academia. This requirements analysis has led to an overall architecture proposal – conceptual and technical – and a roadmap for the development of the MegaM@Rt2 solution (D1.2). Regarding the research and development effort, most of it is concentrated around the aforementioned tool sets, namely, system engineering, runtime analysis and global model & traceability management. Current work on them has focused on providing the state-of-the-art analysis (deliverables D2.1–D4.1); and on the definition of their initial versions (D2.2–D4.2). Next steps involve integrating together these technical results, applying them on the use cases and finally evaluating them for further improvement.

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