



Model-Based Software Engineering at RWTH Aachen University

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Abstract: In this article, the Software Engineering Research Group of RWTH Aachen University presents its research aim, research topics and some research highlights that have been researched over the last ten years. Furthermore, the relevance of agile, generative and model-based software engineering methods for the special interest group Enterprise Modelling and Information Systems Architectures (SIG-EMISA) is discussed.

Keywords: Agile Development Methods · Domain-Specific (Modeling) Languages · Generation of Enterprise Information Systems · Generative Methods · Model-Based Software Engineering · Research

1 The Research Group

The chair of Software Engineering (SE) is one out of 30 research areas of the Department of Computer Science in the Faculty for Mathematics, Computer Science and Natural Sciences of RWTH Aachen University, the largest university for technical studies in Germany. The research focus of SE is the definition and improvement of languages, methods, concepts, tools and infrastructures for the efficient development of software. The chair is currently organized in four working groups: Automotive and Cyber-Physical Systems (ASE), Model-Based Assistance and Information Services (MBAIS), Model-Driven System Engineering (MDSE) and Modeling Language Engineering (MLE). SE is a partner in the Cluster of Excellence *Internet of Production* and co-initiator of the *Center for Systems Engineering* at RWTH Aachen University.

Our teaching activities include courses in Software Engineering, Model-Based Software Engineering, Software Language Engineering and Software Architectures for the informatics bachelor and master curricula as well as for other curricula such as software and systems engineering, data science or mathematics. Following a research driven teaching approach, our exercises and seminar topics are strongly related to current topics such as autonomous driving, digital transformations, model-based assistance and e-health and model-driven systems engineering for cyber-physical systems.

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2 Research Aim and Topics

The history of software development is marked by a series of software projects that have been unsuccessful or have failed altogether: They ran out of time, were more expensive than expected or used the wrong technology. Even if they were regarded as successful from the developer's point of view, they could fail due to the acceptance of the future users. We believe and have successfully demonstrated in various industrial projects that the use of agile, model-based and generative methods could help to overcome such problems.

The aim of the SE group is to improve software and systems development by identifying languages, methods, concepts, tools and infrastructures for developing software systems better and faster in order to achieve a high quality product in less time while incorporating constantly changing requirements in an agile way.

Current fields of research include model-based development of software and systems in an agile manner using generative methods. The input for generators are models created using domain-specific modeling languages. Other topics, which are strongly related to the research focus of the special interest group EMISA, is the modeling of software architectures, enterprise information systems as well as assistive systems. The broad knowledge of the research group is documented in over 200 publications and a series of successful research projects.

Agile, Model-Based Software Engineering (MBSE). Software engineers typically use *models* to be able to understand complex software systems. In model-based development processes, one or more modeling languages are the central notation and replace the programming language as much as possible. To use an executable, abstract and multi-view modeling language for modeling, designing and programming allows to use an agile development process [Ru12; Ru17]. Thus, the SE group has successfully evaluated agile, model-based software engineering in various industrial projects in the areas of embedded systems, autonomous vehicles, IoT, smart buildings, IoP, robotics and cloud systems within the last decade.

Generative Software Engineering. The use of generative methods and MBSE improves the adaptability and reusability of applications, increases the quality of the software and supports iterative development through constant regeneration based on the given models. For product and test code generation, we use the UML/P language family [Ru12; Ru16] as a simplified and semantically sound derivate of the UML. With *MontiCore* [HR17; KRV10], the framework for the creation and processing of domain-specific languages, the SE group has successfully demonstrated the practical application of generative and model-based methods. Projects included requirements analysis, functional, version and variant modelling as well as the development of software and hardware architectures.

Domain Specific (Modeling) Languages (DSLs). For domain-specific needs, MBSE relies on the use of DSLs as a central notation. DSLs can be developed to be used for several purposes such as designing, programming and testing software systems or for describing

the behavior of a system or process. The SE group has already developed a collection of UML/P [Ru11] inspired DSLs such as Class Diagrams for Analysis or the GUI DSL [Ad19]. Moreover, the chair has a sound theoretical knowledge of modelling languages and their semantics [KR18]. Other work in this area focusses, e.g., on guidelines to define DSLs [Ka09].

Modeling Software Architecture. Distributed interactive system architectures rely on the communication paradigm of asynchronous message passing between actors. We built a concrete tooling infrastructure called MontiArc [HRR12] for modeling such distributed interactive systems and their architecture design as well as extensions for states [RRW13]. Current work focusses e.g., on the architecture of cloud services for the digital me in privacy-aware environments [Ei17], or on tool integration via component connector architectures [Da19].

Models in Enterprise Information System Development. Using our experiences in the model-based generation of code with MontiCore, we developed several generators for data-centric applications. The most recent one, MontiGEM [Ad19], was successfully applied in an application project for the financial controlling of the chairs of RWTH Aachen University. [Ad18] presents our approach for the model-based generation of data-intensive EIS in the MaCoCo project. Current research adapts and extends MontiGEM for mobile applications, further graphical representation components as well as the development of information portals.

Model-Based Assistance. Assistive systems support people in carrying out their activities by providing them a just-in-time activity support. Continuing work started at the Universität Klagenfurt [MM13], model-based approaches for assistive systems and their context models [MS17] are under investigation. The mark-up of online manuals for non-smart devices [SM18] as well as websites [SM19] is one further step to provide human-centered assistance. Other aspects are data-structures and architectural decisions for user-centered privacy-driven system design [Mi19].

Besides these research topics, the SE group works on (1) methodologies for software language engineering (SLE), (2) the analysis of the semantics of modeling languages, (3) evolution, transformation, compositionality and modularity of models, (4) variability and Software Product Lines (SPL), (5) the interplay of software and hardware in cyber-physical systems (CPS), (6) the area model-driven systems engineering in which software for modern systems of systems is investigated and developed, (7) the application of state-based modeling (automata) on systems and (8) the application of MBSE in particular domains such as robotics, automotive energy management, cloud computing, Internet of Things(IoT) or industry 4.0. Our domain specific language framework *MontiCore*² features the agile and compositional development of DSLs and forms a basis for further developments and solutions.

²<http://www.monticore.de/>

3 Relevance for the SIG-EMISA

The research topics of the SE group that we have explained in more detail in this paper, contribute especially to the engineering of information systems, services and their architectures, which are as well some main aspects of the SIG-EMISA.³ Our research considers the software development process from a scientific perspective, from the model to the delivered software. The model-based development of software and systems in an agile way with generative methods and domain-specific modelling languages offers a good foundation for the development of information and assistance services and systems based on a stable system architecture.

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³Clearly, members of the SE group are not only involved in the SIG-EMISA: They are also actively involved in the SIG Software Engineering, as well as the cross-sectional committee for modelling (Querschnittsfachausschuss Modellierung) of the german informatics society (GI).

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