Model-Driven Engineering of Embedded Real-Time Systems

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Contents

Chapter 1

Introduction

1.1 Research Topic

Model-Based Engineering (MDE) aims to improve productivity by increasing the return which companies can derive from previous software development effort [1]. The *Composition with guarantees for High integrity Embedded Software componentS assembly (CHESS)* project focuses on the area of design and analysis of extra-functional properties of diverse systems in MDE; the aim is building modeling languages for the specification of such properties based on a common platform-independent component model to be developed and which could be used in several different domains (space, telecom, railways, automotive). Development of tools for extra-functional properties evaluation and provision support for evaluation of software architectures and traceability of non-functional requirements have to be provided. A noteworthy goal of the project is to provide adaptation of component infrastructures for integration of real-time and dependable patterns; it should be possible to integrate the specific design patterns associated to real-time and dependable systems to the software infrastructures, modeling tools and automatic software generators. Moreover validation of the entire approach through innovative dynamic component-based case studies has to be fulfilled. The MDH side contribution to CHESS will mainly involve the Telecom domain. Requirements for the domain have to be formalized in a uniform way and analysis methods have to be specified. Execution platform and rules for transforming from CHESS to platform-specific models have to be specified and knowledge in modeling languages and tools, domain-specific modeling, model transformations, transformation tools, model weaving will be required as well as remarkable research in both component-based and embedded real-time systems. Several code generators from the CHESS modeling language will be needed as well as transformers from analysis tools' output format and the CHESS modeling language for round-trip engineering. Reuse and integration of existing tools will be also relevant. The project results have to be verified and validated through corresponding use cases.

1.2 Research Method

In order to reach the given objectives, several research activities have to be carried out. The component model to be developed has to address several different domains (space, telecom, railways, automotive), therefore a deep investigation of every domain's needs is a central issue to carry out the requirements and specification phase. Decisions must be taken regarding the development of the component model: reuse vs. development from scratch. The available component models have to be explored and compared to the project objectives in order to take such a decision. The component model will be followed to build platform-independent models of the system under development. Through a set of transformations and ad-hoc tools that will be developed or adopted, the system will allow the generation of analyzable code and furthermore analysis results. Evolution, co-evolution and synchronization of models must be handled in order to maintain traceability and consistency among the transformed and enriched models. Knowledge has to be accrued in the areas of model transformations, evolution and co-evolution, as well as model synchronization. The system must eventually provide analysis tools and methodologies for verification and validation; existing model-based analysis approaches and methodologies will be explored.

Chapter 2

Field of Research

2.1 Model Driven Engineering

Model Driven Engineering (MDE) aims at facilitating the system development by creating, maintaining and manipulating models. A possible scenario in an MDE process is the OMG's Model Driven Architecture (MDA), which is based on a distinction between platform independent models (PIM) and platform description models (PDM) that are realized through a set of middleware and programming languages into platform specific models (PSM). The MDE term was first introduced by Kent [1] and includes all modeling tasks needed for the entire software development process. A system is developed by refining models starting from higher and moving to lower levels of abstraction until code is generated; refinement is implemented by transformations over models. Maintaining traceability among models over transformations, consistency and platform independence is not trivial. In fact, the more transformations are applied to models, and higher is the possibility to lose initial information. The need to address several different platforms makes the problem even less trivial. In MoDELS'08 there has been a wide discussion over the most noteworthy challenges in MDE; many of them are highly relevant in the CHESS project and my research area in general and can be summarized as follows [2]:

- **Quality of developed models:** model quality metrics have to defined and guidelines to measure, predict, improve and predict quality have to be agreed. It is also important to assure balanced trade-offs between different and sometimes conflicting quality aspects.
- **Model at run-time:** In order to have a higher applicability in industry, the use of models has to be extended also to the phases beyond the design and implementation. Dynamic behavior has to be represented in some way and the derived run-time models be executed. A relationship between static and dynamic models has to be caught in order to maintain traceability and consistency. In this area a core aspect is the research in code generation techniques which, if well accomplished, could lead to a considerable reduction in the coding effort.
- **Requirements modelling:** the first phases of the software development process concern the requirements specification. In order to have a more complete model-based approach, requirements have also to be modelled and traceability between written informal specification and formal models has to be maintained.

- **Standards:** a set of standards has to be selected in order to facilitate interoperability between different tools used in the same development process. A way of sharing models, model transformations and case studies among them would be very useful.

- **Modelling languages:** development of models involves well-defined modelling languages. Languages, methods and tools have to be selected to fit the needs of the meta-model that has to be created as basis for the further modelling phases. Possibilities for dealing with multi-models and multi-modelling in the same process have to be explored.

- **Domain-specific modelling:** As stated before, the model-based development process consists in a series of model transformations. MDA sees this process as a transit from PIM to PSM models. In order to achieve it, domain-specific modelling languages must be designed and models specified in different languages should be related. Reusability across different domain-specific modelling languages should be increased and code generation facilitated. A certain balance of the trade-off between general-purpose modelling languages and tools and domain-specific ones could be necessary, depending on the specific environment.

- **Model verification and validation:** the latter phases of software development process regard verification and validation. A way to verify, validate and test models and generated code has to be found and automation of test cases generation is a core issue. Validation and verication should be addressed also to a multi-model development.

- **Industrial adoption:** the industrial adoption is not always cost effective. In cases of companies with a large legacy code base written in old technologies, the migration to MDE could imply an unconvenient effort in terms of cost and time.

2.2 Model transformation

Model-Driven Engineering concerns not only horizontal usage of models, but rather a horizontal/vertical combination is preferred. These multiple interrelated models have to be handled paying particular attention to their overall consistency through model syncronization. This is performed through a set of automated processes called model transformations. A model transformation is a particular process which takes, as input, a set of source models and, following specified transformation rules, derives a set of target models as output. The model transformation approaches can be divided into the following categories and subcategories [3]:

- **Model-To-Code**
  - Visitor-Based: it is the simplest approach. It writes code to a text stream by a visitor mechanism which explores the internal representation of the model to be transformed.
  - Template-Based: the approach is based on a template which uses target metacode to access information from the source and to select and interatively expand code.
- **Model-To-Model**

- Direct-Manipulation: these approaches perform model transformation using an internal model representation and some provided APIs plus transformation rules developed usually from scratch by the developer.
- Relational: approaches based on different mathematical relations. Query/Model/View (QVT) is a standard for relation model transformations introduced by OMG.
- Graph-Transformation-Based: these approaches perform transformations by using particular graphs specifically designed to represent UML-like models.
- Structure-Driven: they are characterized by a two-phases process that first creates the hierarchical structure of the target model and eventually sets its attributes and references.

Different approaches can be combined in hybrid approaches in order to fit particular needs.

2.3 Model consistency and co-evolution

Metamodels are a the basis concepts in MDE and are expected to evolve during their life-cycle. This evolution generates not only benefits, since existing models conforming to the initial metamodel version could lose consistency, being no more conforming to the actual metamodel version. The solution for this problem is the introduction of model co-evolution mechanisms, which provide migration of 'old' models in new instances conforming to the evolved metamodel; the metamodel evolution and model co-evolution present many difficulties due to large amount of variables involved [4]. A MDE approach can imply several different developers, modelling languages and tools that model the same system. This wide variety of actors together with model transformations within a single development branch, can lead to inconsistencies both in and between models. The possibility to develop domain-specific modelling languages (DSMLs) with high level of adaption and extension capabilities could help in avoiding some sorts of inconsistencies. A solution would be a rapid prototyping in the DSMLs building in order to have continuous and incremental feedback. This evolution leads to the question of what happens to previous developed models after an evolution of the DSML and how the eventual inconsistencies between different versions may be solved. A need of built-in support for handling of these inconsistencies arises in both model-driven development environments, from models to generated code (model-code synchronization and round-trip engineering), and versioning tools.

2.4 Relevance for the Ph.D. research

My research has MDE as core subject with concentration in model transformation and co-evolution. More specifically, the research will embrace model-based development of embedded systems in the telecom sector with a special focus on modeling system architecture and behavior in order to enable property prediction from models. Techniques that fuse model-based annd component-based software-engineering methodologies will be also of special interest. All these aspects of MDE will be explored in the CHESS project. The research work carried out at Mälardalens Högskola will be mainly devoted to the Telecom domain in collaboration with Ericsson and ENEA, while other domains will be taken care by several other industrial and academic partners.

Chapter 3

The Community

In this section a list of the most relevant papers, research groups and conferences on the research area will be given.

3.1 Seminal Papers

3.1.1 MDE/MDA

In 2002 S. Kent published in Lecture Notes in Computer Science (LNCS) a paper [1] on a framework for model driven engineering, which could be used as reference for activities in this area. Starting from the MDA definition by the Object Management Group (OMG), it goes through the main issues in a model driven engineering approach from how to locate models in the modelling space to how to achieve mappings between models. Importance of several tools is stated and the need of defining families of languages and transformations is arised. J. Bézivin plublished in 2005 a paper [5] which proposes a vision of MDE development based on the previous object technology approach. From the message 'Everything is an object' typical of the object technology, a new message driven by MDE is proposed: 'Everything is a model'. The two core object technology relations, inheritance and instantiation, are so replaced by representation and conformance. The discussed issues are very useful to understand the MDE area in general and the MDA approach in particular.

3.1.2 Model Transformations

MDA aims at automatically generating platform-specific models from platform-independent models. Well-established standards for the modelling phases have been reached, but the specification of transformations between those models is not yet mature. In 2003, K. Czarnecki and S. Helsen proposed in [3] a taxonomy for the classification of both existing and proposed model transformation approaches, which are divided into a small set of major categories based on the authors' analysis. T. Mens, K. Czarnecki and P. Van Gorp proposed in [6] a summary of the results of the discussion of the Dagsthul Seminar on Language Engineering for Model-Driven Software Development. In this paper essential characteristics of model transformations are discussed together with their supporting languages and tools. A comparison between different existing model transformation approaches is provided with a discussion on commonalities and variabilities among them. The paper aims at helping the developer in choosing the model transformation approach which best matches his needs.

3.1.3 Model Consistency and Co-evolution

A. Pierantonio, D. Deridder, J. Gray and P.Y. Schobbens published a selection of the ten higher-guality contributions [7] submitted at the Model Co-evolution and Consistency Management (MCCM'08) Workshop and Symposia hosted by MoDELS'08. Within this set of ten papers, two were selected as best papers: [8], which presents triple graph grammars vs. triple graph transformation systems for a study case and [9] focusing on integration between Object Contraint Language (OCL) and triple graph grammars. In september 2008, A. Cicchetti, D. Di Ruscio, R. Eramo and A. Pierantonio proposed in [10] a set high-order model transformations that, taking a difference model recording the metamodel evolution, are able to co-evolve the models involved.

3.2 Other Relevant Papers

C. Atkinson and T. Künhe published a paper in 2002 [11] in which they discuss the role of meta-modeling in Model-Driven Development and suggest a set of requirements that a supporting infrastructure should satisfy. Regarding the challenges in MDE, R. Van De Straeten, T. Mens and S. Van Baelen wrote a paper in 2009 [2] which, based on the progress in state-of-the-art and state-of-the-practice in MDE, aims at providing a set of MDE research and practice problems that are still unsolved. They summarize different challenges identified by major experts in the field.

3.3 Leading Research Groups

Prof. Jean Bézivin, Faculty of Sciences, University of Nantes, France
The group leaded by Prof. Bézivin focus its research on several aspects of model-driven engineering and more specifically the techniques of model transformation applied to data engineering and to software forward and reverse engineering. Moreover, product and process modeling as well as knowledge-based software engineering and object-oriented analysis and design are part of the research interests.
Prof. Jean-Marc Jézéquel, IRISA, University of Rennes, France
Another French MDE research group, leaded by Prof. Jézéquel, focuses on the domanin of component based reactive and large scale distributed systems with qulity of service constraints. They developed a meta-modeling environment called Kernel Meta-modeling (KerMeta) [12] which defines a core metamodeling toolkit for building model-driven specific tools, product line modeling and derivation tools and model based test cases generation.
Prof. Krzysztof Czarnecki, Department of Electrical and Computer Engineering, University of Waterloo, Canada
Prof. Czarnecki and his research group are highly involved in the model transformation area, and have developed tools for feature modeling and round-trip support for framwework-specific modeling languages.
Daniel Varró, Department of Measurement and Information Systems, University of Technology and Economics of Budapest, Hungary

The Hungarian research team from Univeristy of Budapest has interests in UML, meta-modeling, domain-specific modeling languages, service-oriented architecture, but focuses on model transformations, particularly on graph transformations. They developed a framework called VIsual Automated mode TRAnsformations (VIATRA) [13] which provides a general-purpose support for the entire life-cycle of engineering model transformations from specification to maintainance. Moreover, they contribute for the development of model-driven approaches for the design and analysis of dependable systems, as well as for new ideas in the fields of model checking and theorem proving.
Prof. Alfonso Pierantonio, Department of Computer Science, University of L'Aquila, Italy
The Italian team leaded by Prof. Pierantonio focuses on several specific aspects of MDE such as meta-model evolution, model co-evolution, model synchronization. Of particular interest are theory and practice of model versioning/evolution in the current generic modeling platforms, couple evolution in EMOF-based systems towards a complete automation of the model adaptation procedure and bidirectional model transformations for change propagation and model synchronization.
Michael Lawley, CSIRO Australian e-Health Research Centre, Herston, Australia
The autralian team has done a very valuable research in model-driven development techniques and prototyping languages/tools for supporting model-driven development. Core contribution has been provided on the development of the OMG's Meta Object Facility 2.0 Query/View/Transformation (MOF QVT)
Prof. Bernhard Westfechtel, Applied Computer Science at University of Bayreuth, Germany
The research interests of the german team leaded by Prof. Westfechtel embrace software configuration management and engineering/product data management. In the area of MDE, they focus on software process modeling, management of development processes and reengineering; finally the have particularly contributed in the field o triple graph model transformations.

3.4 Conferences

- *ICSE (International Conference on Software Engineering):* since it can be considered the premier worldwide software engineering conference, ICSE hosts the hottest topics in software engineering, including MDE topics. It provides a forum for researchers, practitioners and educators for discussing about the most recent trends, experiences and innovations in software engineering. During the conference, the ICSE Most Influential Paper is awarded; the paper is choosen, among the papers from the ten years before ICSE conference, as the most influential on the theory or practice in the ten years after its publication [14].

- *ASE (International Conference on Automate Software Engineering):* is one of the world's premier software engineering conferences and usually hosts MDE topics since considered an innovative trend. It brings together researchers and practitioners to share new ideas on techniques, tools and experiences in automated software engineering [15].

- *MoDELS (International Conference on Model Driven Engineering Languages and Systems):* formerly called UML conference, it is a series of conferences entirely devoted to MDE topics, from languages to systems. Model-driven development has been widely used for complex hardware systems, and it is lately becoming more and more present in development of complex software or combined hardware and software systems development. The MoDELS series of conferences provides a forum for discussing innovative technical ideas and experiences about model-driven development of software-based systems [16].

- *ECMDA (European Conference on Model-Driven Architecture):* european conference on the advancing of the MDA technology in industry. The main focus is on engaging key figures of research and industry to achieve more reliable software by the industry on the basis of research innovations [17].
- *ICMT (International Conference on Model Transformation):* international conference focusing in challenges for existing model transformation technology as well as future problems and possible solutions. Practical problems of existing languages, tools, and environemnt for model-transformations will be explored and new ideas and challenges discussed. Special interest of the conference regards the chain between model-transformation theory and tools, together with model-transformations related to different domains [18].
- *TOOLS (International Conference Objects, Models, Components, Patterns):* provides a discussion forum about the most modern approaches in software development with a special focus on Object-Oriented and components. The conference has lately broadened the scope to cover all modern and practical approaches for software development. It focuses on practicality and combination of theory and applications coming from the best academic and industrial experts [19].

3.5 Workshops

- *MoDSE-MCCM (Workshop on Transformation and Weaving Ontologies in Model Driven Engineering):* it aims at discussing the possible ways through which models can help and guide software evolution [20].
- *TWOMDE (Workshop on Transformation and Weaving Ontologies in Model Driven Engineering):* it aims at providing discussions about the application of different aspects of transformation and weaving ontologies to enhance MDE/MDA [21].
- *MoDeVVA (Model Driven Engineering, Verification and Validation):* it focuses on model design, verification and validation and aims at sharing new V&V approaches in the MDE context [22].
- *ACES-MB(Model-Based Architecting and Construction of Embedded Systems):* this workshop brings together researchers and practitiones interested in model-based software engineering for real-time embedded systems at any level: modeling languages, concrete application experiences, model analysis techniques, model-based implementation and deployment [23].
- *AOM (Aspect-Oriented Modeling):* this workshop provides a discussion forum on the impacts of aspect-oriented technologies on software modeling [24].
- *Models@Run.Time (Models at Run-Time):* it focuses on analyzing issues related to developing appropriate model-driven approaches for managing and monitoring of systems' execution [25].

3.6 Journals

- *Software and Systems Modeling (SoSyM):* international journal on theoretical and practical issues about the development and application of software and system modeling languages and techniques. It emphasizes theoretical foundations of modeling languages and techniques and analyses real-world modeling experiences [26].

- *Transactions on Software Engineering and Methodology (TOSEM):* it collects the best papers on the challenge of designing and building of large and complex software systems in every aspect, from specification to maintainance. The focus is not only limited to the methodology but also ti tools, languages, algorithms and data structures [27].

- *Transactions on Software Engineering (TSE):* international journal focusing on well-defined theoretical results and empirical studies in the areas of building, analysis and management of sotware [28].

Chapter 4

Research Plan

4.1 Key Definitions

The followings are core definitions needed to understand research topic and issues:

- *Model-Driven Engineering (MDE):* A software engineering approach that promotes the use of models and transformations as primary artifacts throughout the software development process. Its goal is to tackle the problem of developing, maintaining and evolving complex software systems by raising the level of abstraction from source code to models. As such, model-driven engineering promises reuse at the domain level, increasing the overall software quality [29].

- *Model-Transformation:* A model transformation is a particular process which takes, as input, a set of source models and, following specified transformation rules, derives a set of target models as output.

- *Embedded Real-time System (RTES):* Real-time embedded system is not a standardized term in the software engineering community. Neverthless, some commonalities among the different definitions can be gathered [30]:

  - *Embedded:* in the sense that they are part of a larger system
  - *Domain-specific:* an embedded system, once developed and programmed, has a defined functionality which in most cases does not change throughout its life-time
  - *Real-time:* they have a real-time behavior, which generally means that they have to react, in a strict-timely manner, to the environment they are operating in.

- *Extra-functional Property:* an extra-functional, or non-functional, property of a system specifies criteria used to judge the quality of the system behavior rather than the behavior itself.

- *Component-Based Software Engineering (CBSE):* it is an emerging development paradigm that promises to accelerate software development and to reduce costs and time-to-market by assembling systems from predeveloped software components.

4.2 Hypothesis

The own research has roots in the MDE idea and the combination MDSE-CBSE. MDE simplifies the development process by reducing the overall complexity through models; once defined, business logic models are kept platform-independent. CBSE takes advantages from this, since platform-indendency of such models gives it the possibility to reuse both models and associated analysis technologies for developments within different domains.

4.3 Research Questions

1. *Which is the current state-of-the-art of the technology (methodologies/tools) in model-driven engineering for embedded real-time systems?* The state-of-the-art/practice in the MDE field has to be explored with particular attention to the embedded real-time systems in order to accrue a deep knowledge of what is available for possible reuse or as basis for new developments. The wide area of MDE has to be narrowed around the embedded real-time systems domain and noteworthy challenges should be depicted from the general picture, in order to be able to set needs, objectives and goals for the own research activities. Are the actual technologies enough mature to solve our goals and, if not, can they be a basis for the development of an ad-hoc solution for our domain?

2. *Is there any set of methodologies/tools particularly suitable for the development within the telecom domain?* In the sub-area of embedded real-time systems, the attention must be once again narrowed around the specific telecom domain. Among the methodologies and tools available and depicted in the previous steps as suitable for embedded real-time systems, is there any which is particularly qualified to be taken into consideration for developments in the telecom domain? In that case, are methodologies/tools complete enough to support the whole development process or adaptations, interactions and new implementations are needed?

3. *How can extra-functional properties be modeled and analyzed in order to provide effective predictions on system's quality attributes?* Main focus of my research is modeling and analyzing extra-functional properties of embedded real-time telecom domain systems in order to allow early prediction of the behavior in terms of quality attributes. The final goal is to shorten time-to-market and costs since modifications at design time are usually cheaper and faster than at implementation time. Moreover, early predictions allow modifications of the design artifacts that, once implemented in actual code, will maintain consistency and traceability. Models change and evolve: how do different versions relate to each other and which practices will be used for achieving model versioning? A MDE development process implies model-transformations of different kinds: which are the most appropriate approaches for the particular domain and how co-evolution, synchronization can be achieved in order to keep consistency and traceability?

4. *How can component-based and model-based software engineering methodologies be intersected in order to achieve a development process which gains benefits from both approaches?* Component-based and model-based software engineering are two central topics in the software engineering research since they had

attracted a strong interest by the industry. My research has particular interest in these two methodologies and especially in possible ways to integrate or intersect them in order to achieve a development process which can profit by the advantages deriving from both of them. Possible applicability in the telecom field is also of special interest.

4.4 Expected Results

The followings are the expected results for each research question:

1. A survey on support tools for Model-Driven Engineering of Embedded Real-Time Systems, aiming at exploring the state-of-the-art regarding MDE support tools suited for RTES, will be developed. Benefits and drawbacks will be highlighted as well as the degree of completeness provided by each tool (or set of tools) in supporting an MDE development process, from requirements specification to final implementation phases.

2. A domain-independent modeling language will be developed within the CHESS project. It will have to address needs coming from different domains (telecom, aerospace, railways, automotive), each of which must provide a detailed requirements specification in order to reach a common point; the own research will concern the requirements specification for the telecom domain, the development of the CHESS modeling language and textual/graphical editors, and every needed integration of existing telecom tools in CHESS.

3. The CHESS modeling language will be developed with capabilities for extra-functional properties modeling, but also analysis through model-based testing techniques that has first to be explored and then adapted to the particular CHESS process/tools. The objective is to provide methods enabling early prediction of quality attributes from the models of the system under development.

4. Cross-domain results derived from the CHESS project will be integrated with well-established component-based techniques currently used by Ericsson AB in order to reach a fully model-driven development approach.

Chapter 5

Research Activities

5.1 Time Plan and Milestones

Fall 2009
Planned courses and associated activities/milestones:

- *Research Planning:* the main goal of the course is to get familiar with the own research among all its aspects, and the final goal it to develop a research plan for the Ph.D. degree [31].
- *Empirical Software Engineering Research:* going through four different types of empirical studies commonly used in SE research, for each of them a seminar is given in order to get into the state-of-the-art/practice and most common and important practices. The final goal is the development of an accepted version of the research method chapter to the own upcoming thesis [32].
- *Model-Driven Engineering:* the course aims at providing a detailed view of the MDE field, its hot topics and challenges. The central literature will be explored with particular interest in MDE for embedded real-time systems and a survey of the state-of-the-art of tools and approaches supporting MDE development for such systems will be the final result.
- *Industrial Modeling of Embedded Systems:* since the own research area concerns embedded real-time systems among several domains, this course gives an understanding particularly focused on the rapidly evolving industrial landscape for modeling of such systems.
- *Introduction to graduate education for new Ph.D. students:* the course aims at preparing new Ph.D. students for their upcoming research career. The course gives information regarding most important phases and aspects of graduate studies stretching when you are newly admitted to when you are finishing and possibly going to post graduate studies [33].

CHESS project: involved in WP1 for the definition of telecom requirements in a uniform and formal way.
MILESTONE: completion of the survey on support tools for model-driven engineering of embedded real-time systems.

Spring 2010
Planned courses and associated activities/milestones:

- *Telecom Systems:* since the own research area concerns embedded real-time systems among several domains with particular focus in the telecom domain, this course aims at giving a deep understanding of hot topics and challenges in such domain.
- *Advanced Component Based Engineering:* interaction and fusion of model-based and component-based software engineering are of particular interest for the own research; the course gives an opportunity to learn both theoretical and practical advanced issues in the field of component-based engineering.
- *Open Modeling Frameworks:* open modeling tools and methodologies will be explored in order to accrue theoretical and practical knowledge about Eclipse [34], Eclipse Modeling Framework (EMF) [35], Graphical Modeling Framework (GMF) [36], Papyrus [37] and KerMeta [12].

CHESS project: involved in WP1/WP2 for the definition of the CHESS modeling language and the development of the language editor. Knowledge of the analisys methods will be mature in order to soon start first drafts of analysis engines.
Academic duties: assistance for the Advanced Component-Based Software Engineering master and Ph.D. course.

Fall 2010
Planned course and associated activities/milestones: Advanced Real-Time Systems, which deeply investigates the area of real-time systems, core issue for the own research.
CHESS project: involved in WP2/WP3/WP4 for providing extensive knowledge of usage of modeling languages/tools, domain-specific modeling, model-transformations and model weaving together with research in component-based and embedded real-time systems. Knowledge on extra-functional properties specification, verification and validation has to be also provided.
Academic duties: assistance for the Model-Driven Engineering (MDE) master and Ph.D. course.
MILESTONE: complete courses needed to achieve the amount of points requested for the Ph.D. degree.

Spring 2011
CHESS project: involved in WP3/WP4/WP5 for the specification of the execution platform and rules required for performing transformations from CHESS models to platform-specific models. Knowledge on model-transformation methodologies and tools must be provided.
Academic duties: assistance for the Model-Driven Engineering (MDE) master course.
MILESTONE: Licentiate Thesis Proposal

Fall 2011
CHESS project: involved in WP5/WP6/WP7 for verification and validation of the results coming from CHESS through corresponding use-cases. Activities such as lectures, seminars, publications and events will be also scheduled to give CHESS a proper visibility.

Academic duties: assistance for the Model-Driven Engineering (MDE) master course.
MILESTONE: Licentiate Thesis Defense and Definition of the research continuation.

Spring 2012
Academic duties: assistance for the Model-Driven Engineering (MDE) master course.
MILESTONE: Completion of the CHESS project.

Fall 2012
Academic duties: assistance for the Model-Driven Engineering (MDE) master course.
MILESTONE: Ph.D. Thesis Proposal.

Spring 2013
Academic duties: assistance for the Model-Driven Engineering (MDE) master course and supervision of M.Sc. thesis.
MILESTONE: Gathering results for the Ph.D. Thesis.

Fall 2013
Academic duties: assistance for the Model-Driven Engineering (MDE) master course and supervision of M.Sc. thesis.
MILESTONE: Ph.D. Thesis Defence.

Note that detailed description of time planning has been given only for the licentiate degree period, since further activities have not been defined and scheduled yet.

5.2 Planned Publications

Planning publications at this early phase of the Ph.D. degree is not an easy task. Nevertheless assumptions on a possible approach for publications may be done. The idea is to target two journals and submit as many mature and complete publications to be developed by following an incremental process and so composed by the composition of several minor publications. It starts with a workshop for getting first feedbacks on the idea and depending on the received comments and results, the process may take two different directions: improve the paper and submit to a second workshop for further feedback or, in the case of an already mature work, submit it directly to a medium/main conference. The final step would be the submission for a journal. Currently one main publication has been already defined, and the definition of other two main papers is on-going:

- **Title:** *A Survey on Support Tools for Model-Driven Engineering of Embedded Real-Time Systems*
  Abstract: Complexity of embedded real-time software systems (RTES) increase development costs and time-to-market of such products. Costs deriving from design delays can be considerable due to the failure of most embedded designs compared to the initial expectations. The design complexity derives from the set of special constraints under which embedded systems must operate. In addition, there can be others constraints requiring the embedded system under development to meet real-time deadlines. In order to shorten time-to-market and contain production costs, industries are more and more willing to adopt model-driven engineering approaches, whose main goal is to improve productivity by increasing the return which companies can derive from previous software development

effort. This survey aims at exploring the state-of-the-art regarding MDE support tools suited for RTES. Benefit and drawbacks will be highlighted as well as the degree of completeness provided by each tool in supporting an MDE development process, from requirements specification to final implementation phases.
Status: On-going.
Tentative Deadline: December 2009.

- **Tentative Title:** *CHESS: A Multi-concern Modelling Language, Methodology and Toolset for Model-Driven Engineering of RTES*
  Tentative Abstract: Embedded real-time systems development is time-consuming and costly due to its complexity. The adoption of MDE in the development of such systems in industry is strictly related to the quality of the approach. The goal of CHESS is to create an MDE approach for facilitating the development of real-time and dependable embedded systems applicable in several different domains (automotive, telecom, aerospace, railways). Through the definition of a common platform-independent component model and model-driven technologies, it will be capable of capturing non-functional requirements and maintaining separation of concerns. Correctness by construction and early prediction of system's qualities for guarantees at run-time will be also provided. This paper aims at describing the CHESS modeling language and tools highlighting how the defined MDE development process is fully covered by the CHESS capabilities.
  Status: Under planning.
  Tentative Deadline: To be defined.

- **Tentative Title:** *Analysis, Verification and Preservation of Extra-Functional Properties with CHESS*
  Tentative Abstract: Industry is not always willing to adopt MBSE and CBSE approaches due to several different reasons. One of this might be lack of maturity of methodologies for testing of components composition. In this case, implemented systems are composed by components whose composition has not been fully tested and it could lead to incompatibilities with interacting systems and consequent loss of time and money for the company. This paper aims at providing, through the CHESS project, a solution for lack of testability of components composition. High predictability of quality attributes of the system under development at design time would avoid eventual incompatibilities in terms of expected behavior at implementation time.
  Status: Under planning.
  Tentative Deadline: To be defined.

Note that the listed planned publications will involve several minor ones that will be used to incrementally improve the ideas through feedbacks from workshops and conferences.

5.3 Co-operations

Collaboration and co-operation will be held with my advisors, Prof. Mikael Sjödin and Antonio Cicchetti at Mälardalen University. Since the CHESS project is carried out by a large consortium made of companies and universities, collaboration will be held with them, especially with Ericsson AB and Enea for telecom domain issues. Except for the co-operations within CHESS, possible collaboration could be agreed with the italian research groups leaded by Prof. Pierantonio and Prof. Muccini at the University of L'Aquila, Italy. Several issues for internal collaborations with different groups within the MRTC research center at Mälardalen University, such as the ones leaded by Prof. Ivica Crnkovic, will surely arise.

5.4 Conference Trips

Conference trips will depend on the accepted papers. Nevertheless, a number of target conferences for the coming months may be given together with some recent experiences.

Attended Conferences

- *ICSE'09:* participated and presented at ICSE'09 in Vancouver, Canada, as main developer of one of the six finalist projects within the SCORE Software Engineering Contest.
- *RTiS'09:* attended the summer school SNART'09 within the RTiS '09 Conference at Lund University, Sweden [38].

Target Conferences

- *MoDELS'10:* the coming edition of the most important conference in the area of MDE will be held in Oslo, Norway. A submission for this conference will be taken in high consideration.
- *MDD4DRES)'10:* a possible attendance to this summer school [39] is highly probable, due to its focus on the core issues of my research.
- *SNART at RTiS:* the SNART summer school together with the RTiS conference will be most probably attended every year.
- *ICSE'11:* considerable efforts will be targeted to a paper to be submitted to the 2011's edition of the ICSE, due to its relevance in the community.

Bibliography

[1] Stuart Kent. Model driven engineering. In *IFM '02: Proceedings of the Third International Conference on Integrated Formal Methods*, pages 286–298, London, UK, 2002. Springer-Verlag.

[2] R. Straeten, T. Mens, and S. Baelen. Challenges in model-driven software engineering. pages 35–47, 2009.

[3] K. Czarnecki and S. Helsen. Feature-based survey of model transformation approaches. *IBM Syst. J.*, 45(3):621–645, 2006.

[4] A. Cicchetti, D. Di Ruscio, R. Eramo, and A. Pierantonio. Automating coevolution in model-driven engineering. In *Enterprise Distributed Object Computing Conference, 2008. EDOC '08. 12th International IEEE*, pages 222–231, Sept. 2008.

[5] J. Bézivin. On the Unification Power of Models. 4(2):171–188, 2005.

[6] T. Mens, K. Czarnecki, and P. Van Gorp. A Taxonomy of Model Transformations. In Jean Bézivin and Reiko Heckel, editors, *Language Engineering for Model-Driven Software Development, 29. February - 5. March 2004*, volume 04101 of *Dagstuhl Seminar Proceedings*. Internationales Begegnungs- und Forschungszentrum für Informatik (IBFI), Schloss Dagstuhl, Germany, 2004.

[7] D. Deridder, J. Gray, A. Pierantonio, and P.Y. Schobbens. Model co-evolution and consistency management (mccm'08). pages 120–123, 2009.

[8] Thomas Buchmann, Alexander Dotor, and Bernhard Westfechtel. Triple graph grammars or triple graph transformation systems? pages 138–150, 2009.

[9] Duc-Hanh Dang and Martin Gogolla. On integrating ocl and triple graph grammars. pages 124–137, 2009.

[10] A. Cicchetti, D. Di Ruscio, R. Eramo, and A. Pierantonio. Automating coevolution in model-driven engineering. In *Enterprise Distributed Object Computing Conference, 2008. EDOC '08. 12th International IEEE*, pages 222–231, Sept. 2008.

[11] C. Atkinson and T. Künhe. Model-driven development: A metamodeling foundation. *IEEE Software*, 20(5):36–41, 2003.

[12] KerMeta. Offical website. `http://www.irisa.fr/triskell/Softwares/kermeta`.

[13] VIATRA. Offical website. http://eclipse.org/gmt/VIATRA2/.

[14] ICSE. Offical website. http://www.icse-conferences.org/.

[15] ASE 2009. Offical website. https://www.se.auckland.ac.nz/conferences/ase09/.

[16] MoDELS. Offical website. http://www.modelsconference.org/.

[17] ECMDA 2009. Offical website. http://ecmda2009.utwente.nl/.

[18] ICMT 2009. Offical website. http://www.model-transformation.org/ICMT2009/.

[19] TOOLS 2009. Offical website. http://tools.ethz.ch.

[20] MoDSE-MCCM. Offical website. http://www.modse.fr/doku.php.

[21] TWOMDE 2008. Offical website. http://isweb.uni-koblenz.de/events/TWOMDE2008/.

[22] MoDeVVa 2008. Offical website. http://www.cs.colostate.edu/~ghosh/modevva2008/.

[23] ACES Workshop. Offical website. http://www.modelsconference.org/.

[24] AOM Workshop. Offical website. http://www.modelsconference.org/.

[25] Models@Run.Time Workshop. Offical website. http://www.modelsconference.org/.

[26] SoSyM. Offical website. http://sosym.se-rwth.de/.

[27] TOSEM. Offical website. http://tosem.acm.org/.

[28] TSE. Offical website. http://www2.computer.org/portal/web/tse.

[29] Software Evolution Terminology. Website. http://wiki.ercim.org/wg/SoftwareEvolution/index.php/Terminology.

[30] D. Karlsson. Towards formal verification in a componentbased reuse methodology, licentiate thesis no. 1058. http://www.ep.liu.se/lic/science_technology/10/58/, 2003.

[31] Research Planning Course. Official website. http://www.mrtc.mdh.se/han/FoPlan/, 2009.

[32] ESERM Course. Official website. http://www.idt.mdh.se/phd/courses/eserm.html, 2009.

[33] Introduction to graduate education for new Ph.D. students. Official website. http://www.idt.mdh.se/~tnt/courses/phd-intro-0910/, 2009.

[34] Eclipse. Official website. http://www.eclipse.org.

[35] Eclipse Modeling Framework Project. Official website. http://www.eclipse.org/emf/.

[36] Graphical Modeling Framework Project. Official website. http://www.eclipse.org/gmf/, 2009.

[37] Papyrus UML Project. Official website. http://www.papyrusuml.org.

[38] Real-Time in Sweden Conference and SNART Summer School. Official website. http://www.idt.mdh.se/RTIS2009/, 2009.

[39] Model-Driven for Distributed Real-time Embedded Systems International Summer School. Official website. http://www.mdd4dres.info.