Modelling and Analysis of Real Time and Embedded Systems – using UML

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Abstract: This paper presents an overview on the outcomes of the workshop MARTES on Modelling and Analysis of Real Time and Embedded Systems that has taken place for the second time in association with the MoDELS/UML 2006 conference. Important themes discussed at this workshop concerned (1) tools for analysis and model transformation and (2) concepts for modelling quantitative aspects with the perspective of analysis.

Keywords: Modelling, Analysis, Real Time, Embedded Systems.

1. Introduction

The motivation for holding this workshop is rooted in the increasing request to use UML and related modelling formalisms also for the development of real-time and embedded systems and by their particular needs with respect to modelling concepts and analysis.

Even more than in other domains, in the context of real-time and embedded systems, the idea of model-based development, where models representing specifications of software and system level aspects are compiled into code for particular platforms, is highly attractive. In such systems, the inherent complexity due to the presence of concurrency makes a posteriori analysis difficult. Moreover, for safety critical systems the need for certification requires a rigorous design process. Replacing – at least partly – code-based analysis by model-based analysis and coding by an a priori valid code generation method, is extremely attractive then: it allows both to achieve higher quality and speed up the development process.

In particular application domains, tools supporting such an approach have been developed already in the past. Good examples are the Esterel and the SCADE tools [Est] for the development of real-time controllers with guaranteed properties for specific, and relatively simple platforms. These tools come with a set of theories which allow establishing the correctness of the implemented methodology and code generation technique as well as with a set of analysis and verification tools supporting the methodology.

In order make this attractive approach available for a wider range of applications and for a less restricted set of modelling paradigms and platforms, the above mentioned modelling languages need to be enriched – in particular for distributed and performance oriented systems, as well as for modelling relevant aspects of the target platform architecture. Tool support needs to be provided for such richer frameworks. The targeted systems are intrinsically more difficult to analyse, and finding new compromises between flexibility, performance and analysability remains a great challenge. UML provide a rich syntactic framework that can be used for this purpose, but tool supported frameworks have still to be defined.

The main topics of the MARTES workshop were:

1. **UML profiles** or other **modelling languages** which both attack this challenge and come with a semantic underpinning.
2. **Analysis methods and tools** that are useful for such modelling languages and are or could be integrated in the development process. Tool support concerns model-based analysis and validation, compilation and model-transformation, as well as analysis of such transformation methods.
3. Finally, demonstrating the practical **applicability** of such modelling languages and tools for real time and embedded applications on hand of **case studies**.

An additional goal was to bring together researchers from academia and industry to discuss and progress on these issues, as well as other issues in the context of time, scheduling and architecture in UML and UML-related notations..

2. The issues discussed at the workshop

Nine quality contributions were presented at the workshop, backed by a full paper or by a shorter position paper. All the papers together are available on the workshop webpage[1]. 50 participants from academia and from industry underline the importance of the topics discussed.

We give an overview on the topics addressed by the different papers and discuss how they are related. All main topics were addressed and approached even from quite different angles. We note some general tendency to work on modelling concepts and methodologies by relegating the issues related to analysis to a later point of time. We believe that it is of uttermost importance to conceive the concepts jointly with appropriate methods supporting analysis and code derivation. From the discussion at the workshop, it becomes quite obvious that no modelling language or UML profile will suffice in a development process if there is no appropriate tool support, going well beyond graphical editing tools.

Two papers appear in these proceedings; they have been selected by considering their intrinsic quality but also the particular interest with respect to the aims of this workshop.

[1] See http://www.martes.org/ provides access also to the proceedings [GGH*06]

2.1 Profiles and modelling languages

A first step to the inclusion of extra-functional characteristics into the modelling framework has been achieved by the "UML profile for Schedulability, Performance and Time" [OMG03]. More recently, several efforts have been and are being undertaken to improve this initial proposal in several aspects, e.g. to integrate the profile with UML 2.0 rather than UML 1.4.

- A "UML Profile for Modelling Quality of Service and Fault Tolerance Characteristics and Mechanisms (QoS)" [OMG04].
- The IST project Omega aimed also at the definition of a UML profile for real-time and embedded systems with a semantic foundation [GOO05] and with tool support for validation [OGO05]. The resulting profile defines a set of modelling elements, expressive enough to define a precise semantics for all the time constraints introduced in SPT as tag values or stereotypes by means of constraints between well defined occurrences of *events*.
- The MARTE profile has a larger scope. It addresses all concepts important for real time embedded systems.

In last year's workshop [GGH+05], some aspects of it have been discussed, in particular the domain model for analysis relevant quantitative annotations [EGP+05]. This year an almost achieved version of this aspect of the MARTE profile has been presented in [EMD+06].

[ACS+06] refers also to MARTE. It introduces "logical clocks" as a means for characterizing semantically all the time constraints expressed by the above mentioned annotations in terms of constraints on clocks, where *clocks* correspond to *events* of the Omega profile [GOO05], but the way of expressing constraints is different, and in fact not fully defined yet for [ACS+06].

[HKH06] introduces extensions to UML2 sequence diagrams which offer support for more complete and precise behaviour specifications. The mechanism of *exceptions* proposed in [HKH06] is very expressive for capturing behaviours triggered by violated constraints, and shows good qualities concerning refining and composability. The immediate applicability and the level of user interest in these results explains why the paper is included in these proceedings.

2.2 Techniques and Tools

Several contributions presented tools that performed some analysis based on descriptions in their targeted profile of UML. They represent some step towards frameworks for tool supported UML-based development, but much more is still needed.

[NWW+06] was chosen to appear in this volume since it presents promising new ideas to cope with growing complexity of embedded systems. Backed by an impressive prototype tool they showed how traditional graphical modelling can be supplemented by rule-based specification in a domain specific language. The rules for model configuration are then fed to a constraint solver that may also guide the developer through the configuration.

[SG06] gives a way to describe performance characteristics of a product line in a UML profile and how to analyze performance systematically from such descriptions.

Similarly, [RGD+06] presents an improved profile targeting software radio and a corresponding tool for rapid prototyping and investigating performance of such systems. Finally, [GHH06] applies the author's previously presented approach, Mechatronic UML, to hard real-time modelling problems such as issues of individually drifting clocks.

2.3 Applications

On the side of applications, this year we focussed on system-oriented specifications including real-time and safety critical requirements. The [CBL+06] contribution discussed the modelling in SysML of a known benchmark system specification, and provided insight on the application of this emerging standard as well as comparisons to a general language like UML 2.

2.4 Discussion and conclusions

The outcome of the discussions and requests from the audience -- in particular those responsible for designing and developing software for real-time and embedded systems – underlines the importance of tool support for the entire development process, from high level models to running code. This tool support must also include those new concepts and paradigms that appeared more recently in the context of real-time and embedded systems in order to cope with always more complex systems in which concurrent and distributed software, including local and wide area distribution, are of steadily increasing importance.

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