Applying MDE to Embedded System Design

First results and perspectives from the Lambda project

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The Lambda project

Platform providers
- ARION
- PrismTech
- AdaCore
- atego
- kontron

Industrials
- Thales
- STI
- AIRBUS

Tool vendors
- ESTEREL
- CoFluent
- beo

Academics
- INRIA
- Supélec
Challenges, Stakes

- Only 20% of actors in the Embedded Industry players are willing to see development standards appear (*)
- 77% of companies want to keep control of their computing platforms (*)

Incompatible with complexity and productivity challenges

We foster apparition of standards
We foster use of COTS technologies

- Control of complexity: Offensive architecture
  - Multidomain Off-The-Shelf engineering

- Imperfect control of complexity: Défensive architecture
  - Segregation of problems

(*): French Ministère de l'Industrie, Syntec informatique and RNTL
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Interoperability

Design supported by tools

Standards

Knowledge of key characteristics of execution platforms (analysis or simulation)

Feasibility

Realisation of model-driven software engineering

Stake: Maturity at Entry In Service
Execution platform modelling
Example of systems engineer’s issues

Image processing function
(Application)

Optimize CPU consumption?

Component deployment strategies?

Latency / Throughput?

Network configuration
(VLAN, buffers, MTU)

Component frameworks
Single-Board Computers
    (bi-processors, dual-cores)
FPGA accelerators
Gigabit Ethernet

Kontron high performance rack
(Platform)

Requirement: End-to-end processing time less than 100 ms

System Integrator
Execution platform modelling
Models to facilitate integration and validation

- System integration issues
- Difficulties when configuring COTS components

Key role of platforms in the design process of embedded systems
Execution platform modelling
SysML/MARTE as pivot language

Safety Critical Systems
High-Performance Computing
Electronic System Level

Consumer electronics
SystemC / IP-XACT simulation

Avionics systems
Early Validation
Worst-Case Response Time

Image / data processing
Hybrid simulation techniques
Execution platform modelling
Building the platform models

1. A reference application is known and available (e.g. Arion Real-time Ethernet demonstrator)

2. The platform is characterised and modeled in SysML/MARTE along with timing analysis tools

3. Models are calibrated and validated against actual measurements on the platform

4. Validated models are packaged in reusable libraries, contributing to an end-to-end analysis
Execution platform modelling
Current results

- Platform models available in analysis/simulation tools to support dimensioning and deployment
  - Computing platforms, networks, software runtimes

- Key methodological findings
  - A combination of SysML and MARTE provides relevant support to capture application needs and platform capabilities
  - Difficulty to get started with MARTE with no support from experts
    - After a first stage, common practices appeared around a limited subset of MARTE (e.g. NFP, Time model)
  - No « silver-bullet » simulation/analysis technique relevant for all the experimentations
    - Different practices in the Safety-critical, HPC and ESL communities

- On-going work to write synthesis and conclusions
**Interoperability**

- Design supported by tools
- Standards
  - Knowledge of key characteristics of execution platforms (analysis or simulation)

**Feasability**

**Realisation of model-driven software engineering**

**Stake:** Maturity at Entry In Service
Integration and interoperability
Addressing key obstacles to a full-scale deployment of MDE

- Full-scale deployment of MDE in the Industry requires a consolidation of the developed modelling infrastructure
  - Model repositories
  - Model injection and transformation tools

- Several studies and prototyping activities to:
  - Identify key issues
  - Anticipate solutions
  - Start to specify the features of 2\textsuperscript{nd} generation MDE tools

- Themes addressed
  - Maintenance Repair and Operations (MRO) of modelling workbenches
  - Paper studies and benchmarks to assess scalability of modelling repositories and model transformation tools
  - Studies on integration of synchronous languages with SysML/MARTE
  - Integration of non-functional properties in SysML
Integration and interoperability

Current results

- Elements of the complexity under study
  - Managing a large number of artifacts.
  - Managing large scale artifacts.
  - Complexity of relations between artifacts.
  - Using model repositories
  - Building and using libraries of reusable modeling artifacts
  - Managing traceability
  - Managing geographical distribution
  - Managing collaborative work
  - Managing metamodels evolution
  - Configuration management for models
  - Managing multiple viewpoints
  - Managing model engineering workflows and dataflows
  - Managing technological heterogeneity
  - Managing complex systems
  - Managing unbounded models (data flow, infinite streams)
  - Managing legacy systems
  - Definition of a complex system management workbench
  - Ergonomic and rendering issues due to large number of artifacts

- Follow-up work in the context of the ANR Galaxy project
Project overview

Interoperability
Design supported by tools

Standards
Knowledge of key characteristics of execution platforms (analysis or simulation)

Feasibility

Realisation of model-driven software engineering

Stake: Maturity at Entry In Service
Different engineering standards for embedded systems design, defined by different communities
Continuity between SE/SW and SE/HW flows requires interoperability between supporting standards.
Stakes of standard/tool convergences

Current situation

- Standard adoption may face a certain inertia
  - Overview of implemented and commercialized standards:

<table>
<thead>
<tr>
<th>Standard</th>
<th>Date adoption</th>
<th>Date implantation</th>
<th>Solutions commerciales (COTS, OSS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UML 2</td>
<td>2003</td>
<td>2005</td>
<td>15</td>
</tr>
<tr>
<td>SysML</td>
<td>2006</td>
<td>2006</td>
<td>8</td>
</tr>
<tr>
<td>MARTE</td>
<td>2007</td>
<td>2009</td>
<td>2</td>
</tr>
<tr>
<td>AADL v1</td>
<td>2004</td>
<td>2007</td>
<td>1</td>
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<tr>
<td>SystemC-TLM2</td>
<td>2008</td>
<td>2008</td>
<td>10</td>
</tr>
<tr>
<td>IP-XACT</td>
<td>2006</td>
<td>2006</td>
<td>29</td>
</tr>
</tbody>
</table>

Sources: OMG UML/SysML vendor directory, vendor web sites

- Some technical domains seem to deal better with the situation (e.g. ESL) Why?
- Standard adoption requires coordinated collaboration between tool vendors and end users
1. Consolidate a key subset of SysML/MARTE at OMG
2. Ensure alignment of this subset with SAE AADL v2
3. Bridge the gap with standards and adopted practices in ESL (SystemC, IP-XACT) and Software communities (Ravenscar)
Lambda standardisation activities
Current results

- Finalization of the MARTE 1.0 standard
- Elaboration of a mapping of MARTE and AADL
  - Acknowledged by OMG and SAE communities
- Comprehensive support for physical quantities in SysML 1.2
  - Collaboration with ESA and NASA experts
- Joint-response by Lambda partners to the "Future of UML"
  - Thales, Airbus, CoFluent, INRIA, Adacore
  - A common vision for embedded system design
• Collaborative R&D projects constitute good environments for standard elaboration or evolution

• Involvement of end users AND vendors is key to ensure standard adoption

• Standardisation is a long-term effort
  ▪ Defining a new standard at OMG: ~3 years
  ▪ First implementations of OMG standards: +2 years

→ Need to define a step-by-step strategy to deal with impedance mismatch between R&D projects and standards
Conclusions

- The work carried out in the Lambda project demonstrated the importance of platforms in the embedded system design process
  - For end-users, platform vendors and tool vendors
  - Towards a market of model libraries and supporting tools
- First feedback from the modelling experiments: on the need of methodological support to get started with SysML and MARTE
- Integration and interoperability studies started to address key obstacles to a full-scale deployment of MDE in the Industry
  - MRO of modelling workbenches
  - Scalability of modelling tools
- Cross-fertilisation between modelling experiments and standard activities fostered convergence between standards and tools
- The final year of the project will focus on dissemination and standardisation activities in the community