Effective Reduction of Avoidable Complexity in Embedded Systems

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Introduction and Background

Embedded Systems are moving towards Model-Based Engineering

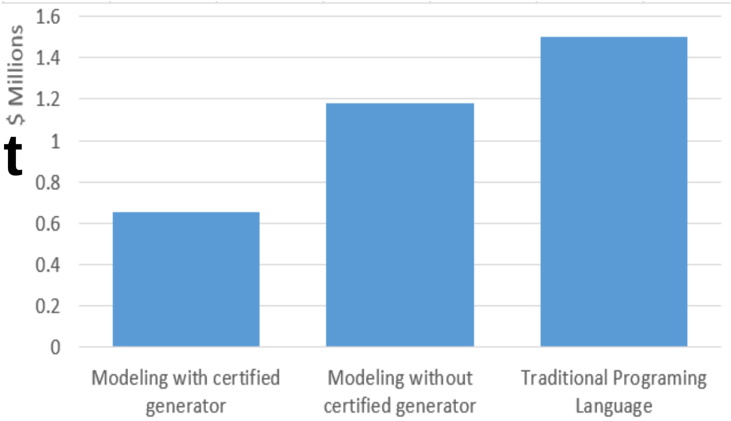
- A380 control and display system implemented with SCADE
- Reduction of **development costs** as much as 57% for highest criticality levels

Software Complexity spans along the software lifecycle

- Impacts development & maintenance activities
- Maintenance = 70% of Total Cost

Need for software complexity management

- How to detect complexity in models?
- How to improve model design?



Costs savings using Model-Based Engineering (DAL A software)

SEI Approach for Software Complexity in Models

How to identify complexity in software models?

- Application on functional (SCADE) and runtime (AADL) models
- Reuse existing metrics vs. develop model-specific ones?

Understand why/when/how users introduce complexity

- Establish user vision of complexity
- Tool support to detect and automatically avoid complexity

Estimate the cost of complexity for safety-critical systems

- Impact on development and maintenance activities

Defining and Detecting Software Complexity

Define inappropriate modeling patterns & complexity metrics

- Runtime models (AADL): complexity in configuration and deployment
- Functional models (SCADE): complexity in software implementation

Identify root causes of high complexity

- Software re-use (aka copy/paste), data scope, etc.
- How to address and fix it (e.g. re-factoring, resources allocation)

Application to existing models

- Stepper Motor (Rolls-Royce/AEC)
- Flight Control Guidance (SCADE)

Software Architecture Complexity (AADL)

Resources usage/dimension, configuration issue

- Two inter-dependent subprograms deployed on different processors
- Communication queues dimensions wrt timing requirements
- Inconsistent timing requirements with connected component

Suggest architecture changes

- Change deployment strategy (e.g. relocate a task)
- Modify timing requirements/communication policy

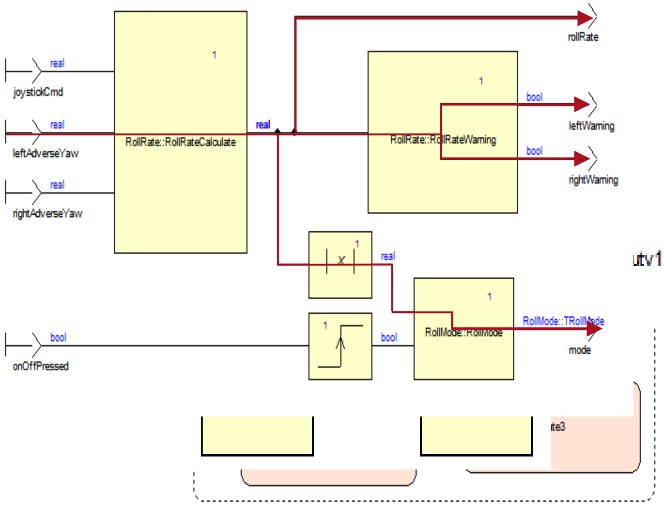
Tested on industrial example

- Discover timing issue from industrial models

Software Functional Complexity (SCADE)

Tailor existing metrics to a modeling language

- System States (cyclomatic)
- Operators and Operands (Halstead)
- Connectedness (Zage)



Develop new model-specific metrics

- Data flow oriented (#operator, #output per flow)
- Help to reason about the impact of a flow
- Provide hints to re-architect the software architecture

Understand Model Complexity

Part 1: Model Review and Tool Usage Critique

Existing model to review (elevator model)

Evaluate the modeling tool (SCADE)

Part 2: Model Design

Implement a system (microwave) from a textual specification

	Student	Professional
No Experience	Group 1	Group 2
Moderate Experience	Group 3	Group 4

Modeling Tool Experiment - Results

Basic complexity issues are not understood

- **50%** of participants have issues with data abstraction
- **50%** of participants have issues with data scope

Appropriate training is key when transitioning to a MDE approach

- 25% of users experienced comprehension and understanding issues
- **80%** of participants did not find any comments (and there were some!)

Experience level does not explain performance

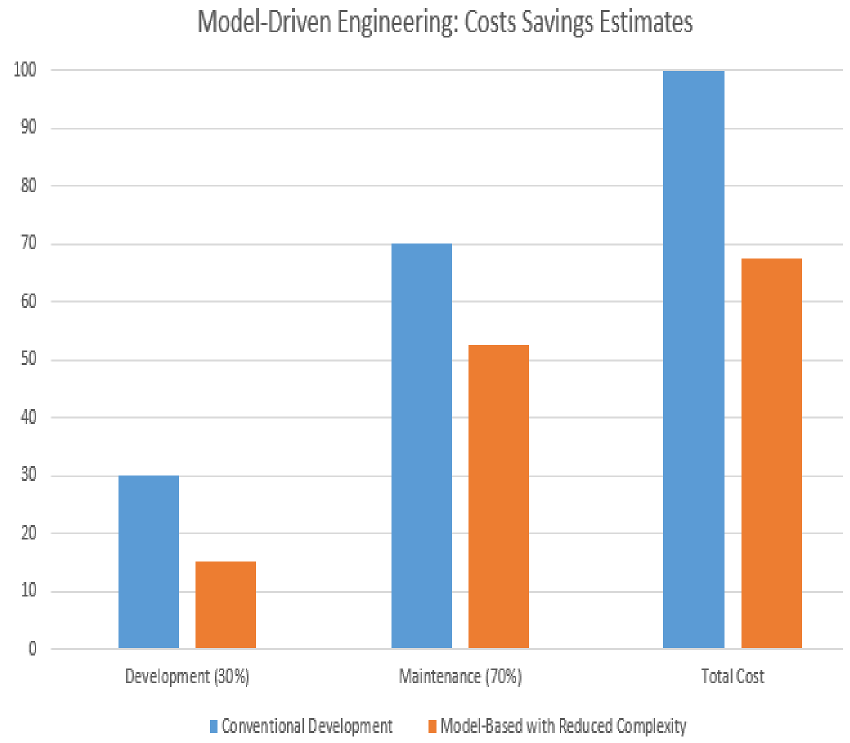
Estimate Cost Savings

Overall impact of Model-Driven Engineering on software quality

- Automatic production of certified code
- Testing and Validation activities, especially for DO178-C
- Software reuse and maintenance

Impact of Models Complexity

- Limited in developments efforts
- Significant in maintenance costs



Adapted from incoming SEI technical report
"Evaluating and Mitigating Complexity in Software Models"

Model-Driven Engineering with managed complexity reduces up to 30% of total TCO

Conclusion and Perspectives

Impact of complexity management with Model-Driven Engineering

- Costs savings of more than 30% on the total life cycle
- Deliver better quality, faster at an affordable cost
- Require **appropriate training** and understanding of modeling techniques

Need to refine complexity metrics on models

- Calibration on several models
- Estimate potential savings per metrics

Transition and impact of SEI research

- Release of tools, integration in modeling software
- Research results published in an SEI technical report, blog and podcast
- Benefits for other domains (e.g. medical, automotive, etc.)

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