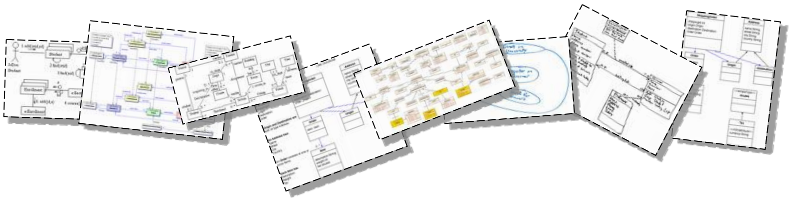
Insights on Applicability of MBSE & Use of MBSE in Optimization of System Design



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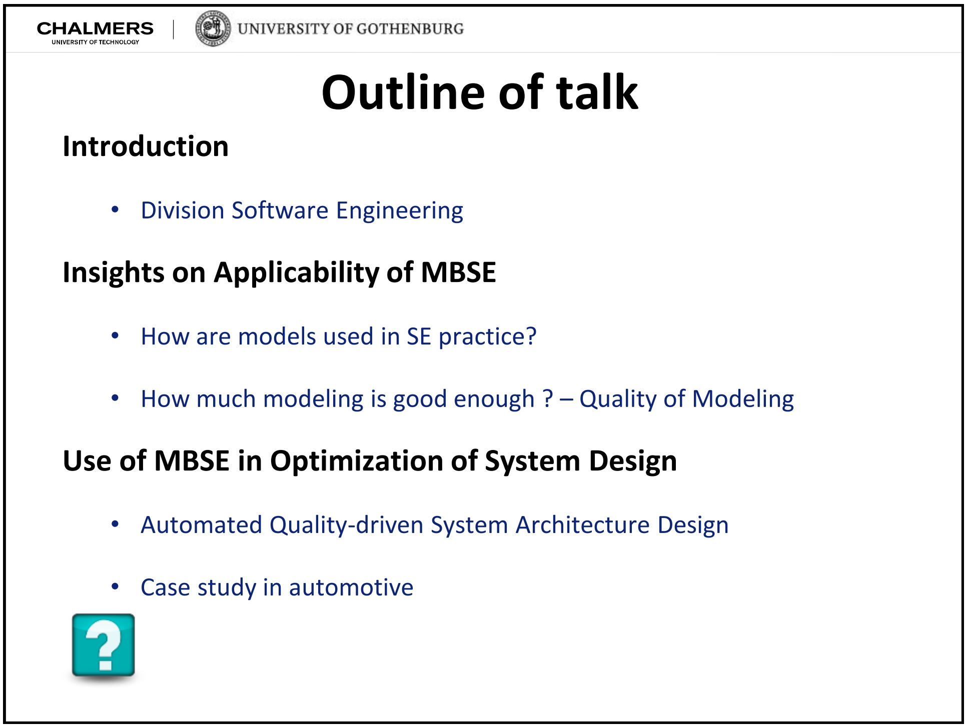
Link to publications

- http://dblp.uni-trier.de/pers/hd/c/Chaudron:Michel_R=_V=



Outline of talk

Introduction

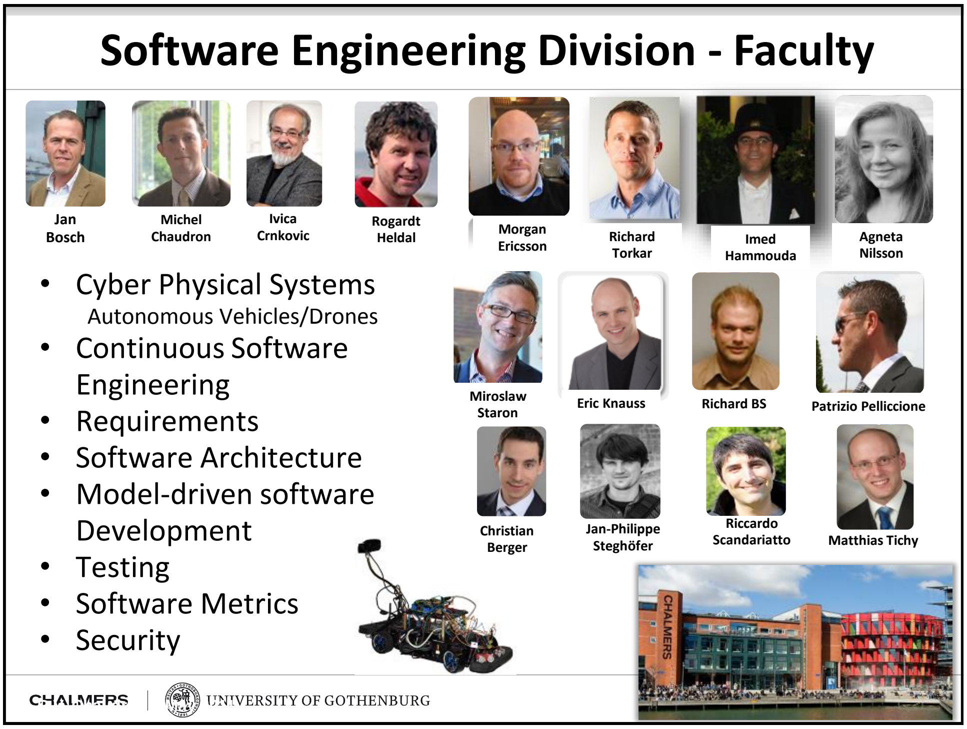
- Division Software Engineering

Insights on Applicability of MBSE

- How are models used in SE practice?
- How much modeling is good enough ? – Quality of Modeling

Use of MBSE in Optimization of System Design

- Automated Quality-driven System Architecture Design
- Case study in automotive



Software Engineering Division - Faculty

Jan Bosch

Michel Chaudron

Ivica Crnkovic

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Agneta Nilsson

Miroslaw Staron

Eric Knauss

Richard BS

Patrizio Pelliccione

Christian Berger

Jan-Philippe Steghöfer

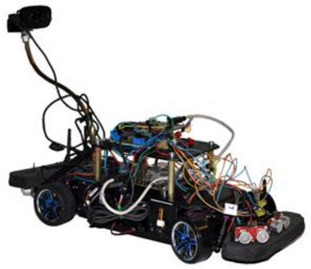
Riccardo Scandariatto

Matthias Tichy

- Cyber Physical Systems
  Autonomous Vehicles/Drones
- Continuous Software Engineering
- Requirements
- Software Architecture
- Model-driven software Development
- Testing
- Software Metrics
- Security

Education Programs

- Software Engineering and Management
  - Combines technical skills with business skills
- Project-based learning
  - Self-driving miniature vehicles
- Model-based software engineering
  - Started using Papyrus in 2014
- Internship – often with industry
  - Volvo, Ericsson, Saab, …



My Background

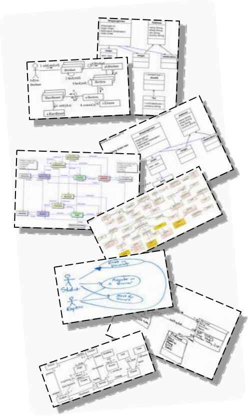
- Since 2012 Prof. in Software Engineering in Gothenburg, Sweden

- **Background**
  - Ph.D. in Formal Methods: Calculi for program derivation (formal methods, concurrency, process algebra)
  - Visiting student/researcher in the UK.
  - 2 years in industry as IT consultant
  - Assistant & Associate prof. at TU Eindhoven & Leiden, Netherlands

- **Industrial research collaborations**
  - Software Architecture, Design & Modeling, Component-based SE
  - Enterprise Architecture, IT Portfolio, Alignment, Agility
  - Research Collaborations: EU/ITEA – o.a. Philips, Nokia, CSEM, also: KLM, ING, T-mobile, Shell, Capgemini, KPMG

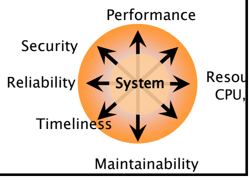
Introduction: Research Interest

- **Is software modelling effective?**
- **What are the pay-offs of investing in early design/architecture/modeling?**
  Fewer defects?
  Cheaper maintenance? …

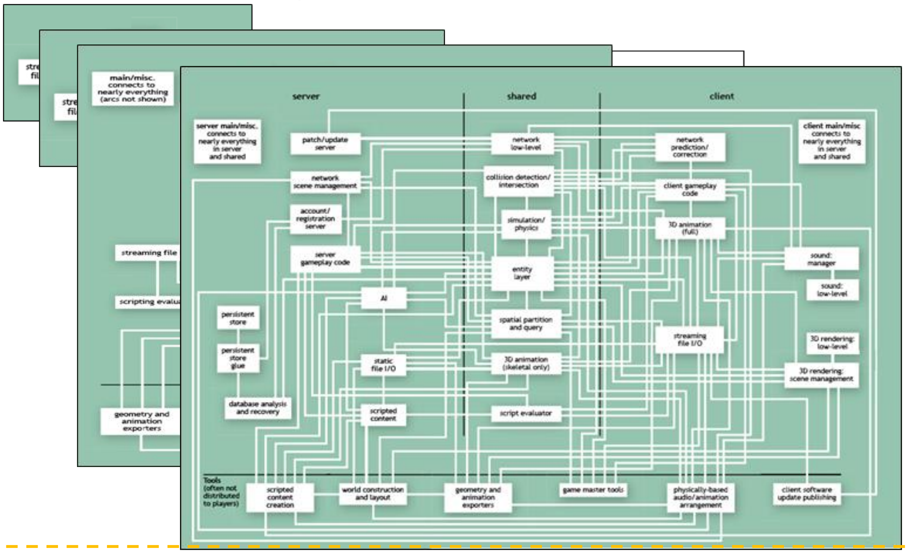


- **Analysis and Reasoning about Extra-Functional Quality Properties of System Architectures**

- Many modeling approaches around;
  focus on UML in custom software development



Increasing Complexity of Software


stre
fil
stre
fil
main/misc. connects to nearly everything (arcs not shown)
streaming file
scripting evalu
geometry and animation exporters
server
shared
client
server main/misc. connects to nearly everything in server and shared
patch/update server
network scene management
account/ registration server
server gameplay code
AI
persistent store
persistent store glue
database analysis and recovery
static file I/O
scripted content
network low-level
collision detection/ intersection
simulation/ physics
entity layer
spatial partition and query
3D animation (skeletal only)
script evaluator
network prediction/ correction
client gameplay code
3D animation (full)
streaming file I/O
client main/misc connects to nearly everything in server and shared
sound: manager
sound: low-level
3D rendering: low-level
3D rendering: scene management
Tools (often not distributed to players)
scripted content creation
world construction and layout
geometry and animation exporters
game master tools
physically-based audio/animation arrangement
client software update publishing

Blow, J. "Game Development: Harder Than You Think." *ACM Queue*

Modeling is inevitable, Automation is needed

Insights on Applicability of MBSE

- Work with ph.d. students:
  - Johan Muskens (Eindhoven)
  - Christian Lange (Eindhoven)
  - Werner Heijstek (Leiden)
  - Ariadi Nugroho (Leiden)
  - Hafeez Osman (Leiden)

The Model-based SE Spectrum

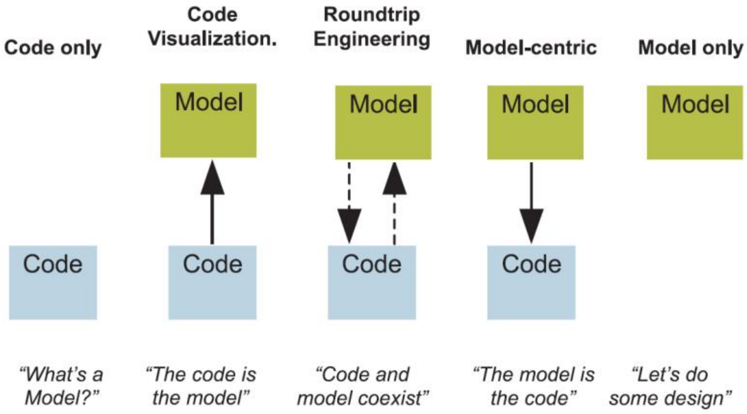
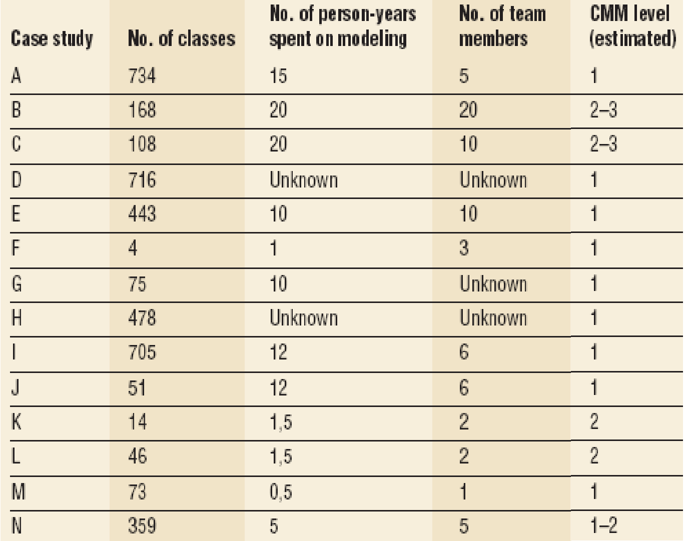


Fig. 1. The modeling spectrum

'Model' means different thing to different people

Model driven architecture: Principles and practice, Brown, A.W., Software and Systems Modeling, 2004

Phase 1: Explore via Case Studies



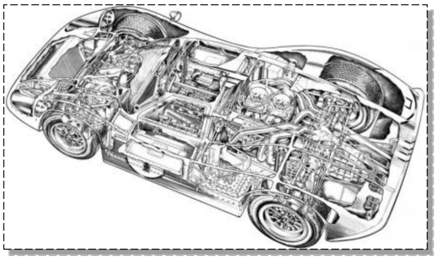
Case study	No. of classes	No. of person-years spent on modeling	No. of team members	CMM level (estimated)
A	734	15	5	1
B	168	20	20	2–3
C	108	20	10	2–3
D	716	Unknown	Unknown	1
E	443	10	10	1
F	4	1	3	1
G	75	10	Unknown	1
H	478	Unknown	Unknown	1
I	705	12	6	1
J	51	12	6	1
K	14	1,5	2	2
L	46	1,5	2	2
M	73	0,5	1	1
N	359	5	5	1–2

Your project here? Mail me: chaudron@chalmers.se

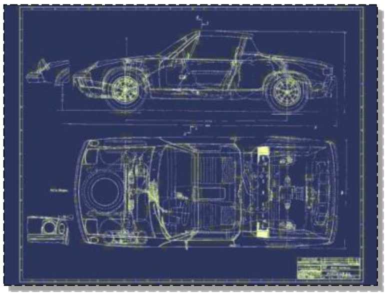
Styles of Modeling

Sketch

Communication

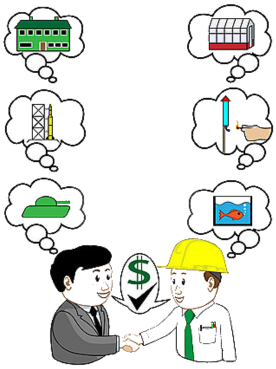


Recipe for construction



Models in Software Development

- + Understanding
- + Communicating
- + Analysing / Predicting
- + Guiding

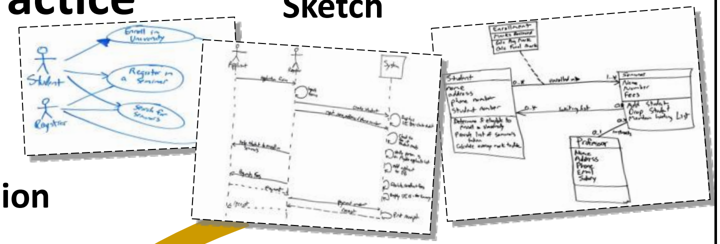


On-boarding new members
Distributed development
Easing maintenance

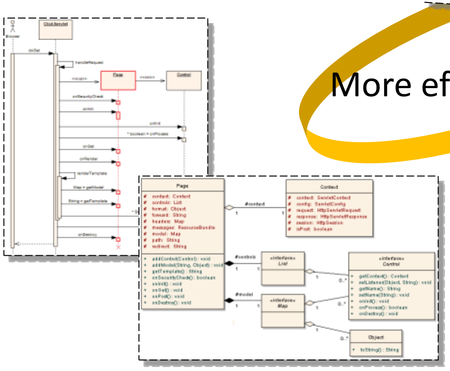
Doing modeling is a quality improving activity

UML in practice

Sketch

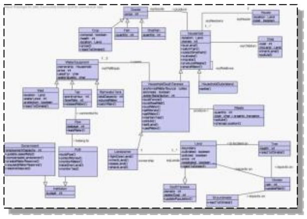


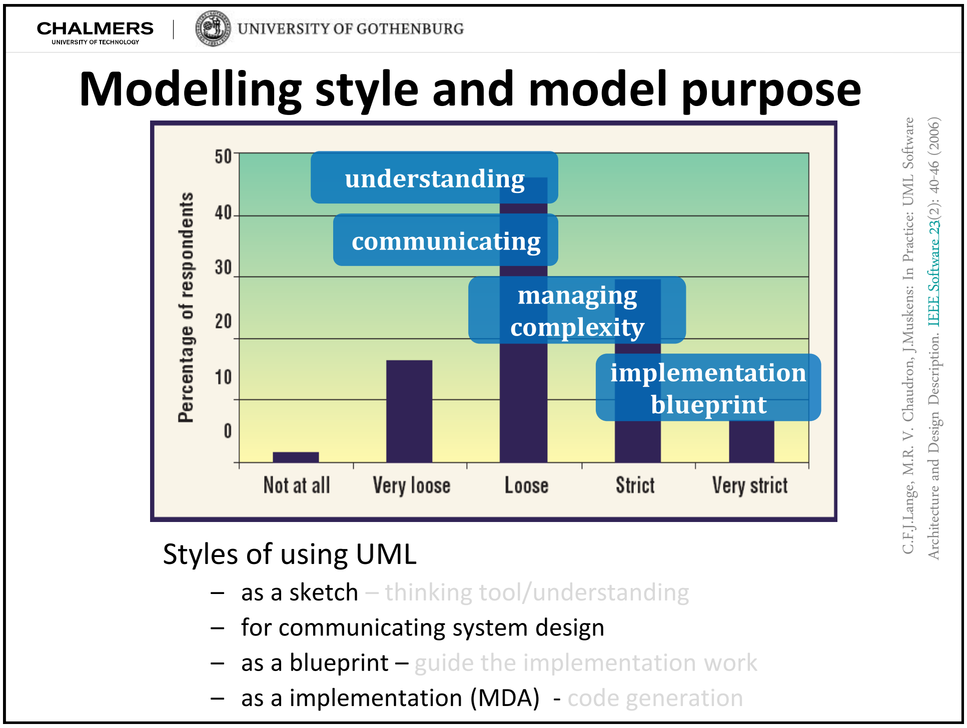
Communication



More effort ⇨ More expensive

Recipe for construction



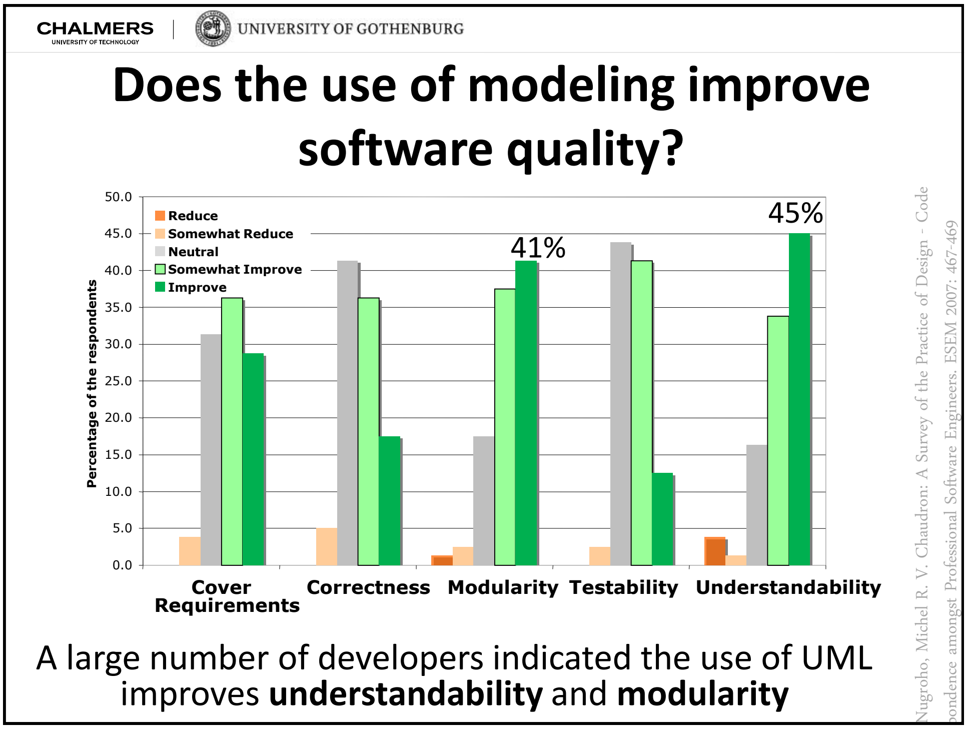


Modelling style and model purpose

Styles of using UML

- as a sketch – thinking tool/understanding
- for communicating system design
- as a blueprint – guide the implementation work
- as a implementation (MDA) - code generation

C.F.J.Lange, M.R. V. Chaudron, J.Muskens: In Practice: UML Software Architecture and Design Description. IEEE Software 23(2): 40-46 (2006)

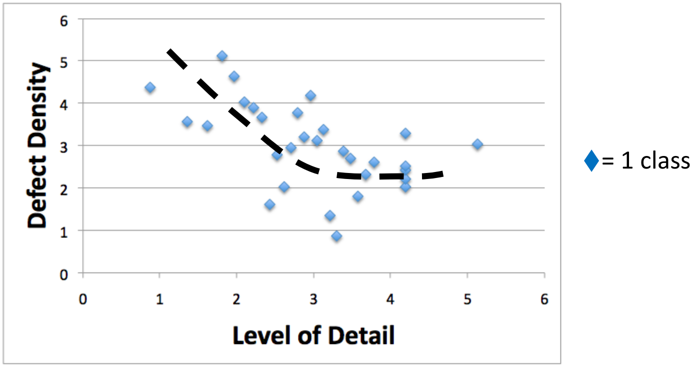


Does the use of modeling improve software quality?

A large number of developers indicated the use of UML improves **understandability** and **modularity**

Nugroho, Michel R. V. Chaudron: A Survey of the Practice of Design - Code
pondence amongst Professional Software Engineers. ESEM 2007: 467-469

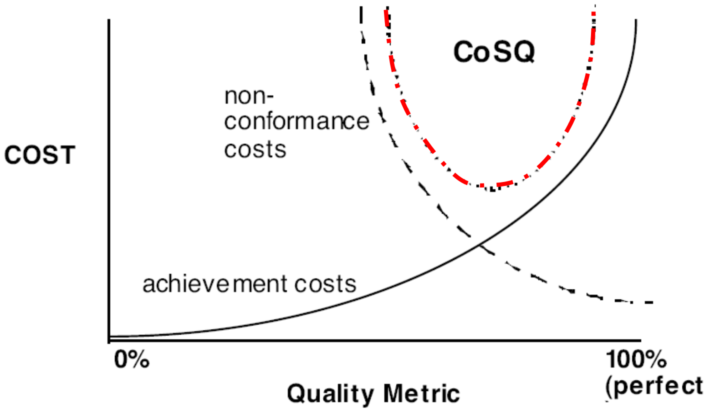
Relation between Level of Detail and Defect Density



Level of Detail for Sequence Diagrams (i.e. behavior models) is significantly (negatively) correlated with defect density.
More detailed model => fewer defects

What about class (i.e. structure) diagrams?

Economic Model for Cost of Quality



From: H. Krasner, Cost of Quality, 1998

Cost of SQ = Achievement Cost + Non-conformance Cost

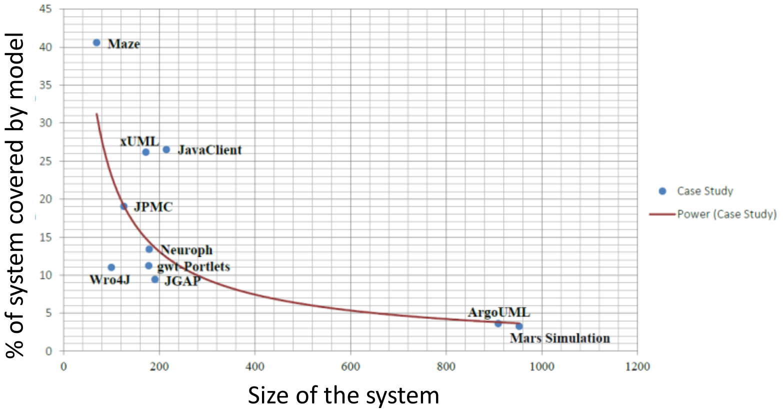
Experience in Formal Modeling

- BOS project (1998)
- At CMG (later Logica, now CGI)
- Safety Critical project
- Fixed-time, fixed cost project

- Applied Formal Methods
  - Promela and model-checking
  - But only for critical properties
  - Also: reviewing and inspections
  - Modeling effort proportional to risk

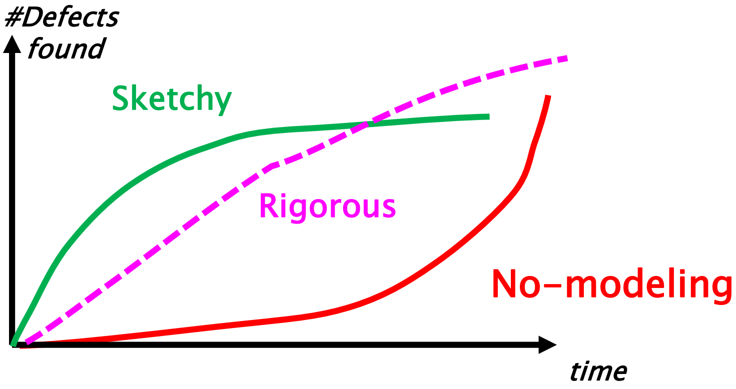
- CMG started business offer: center for critical software

Economy of Modeling



Chaudron’s conjecture

Modeling finds defects early



Does modelling find the right defects?

Quality Assurance for Software Design / UML Model

- How to assess quality?
- How to check conformance of code to design?

How to assess quality UML models?

Design Heuristics

- Coupling, Cohesion, absence of anti-patterns

Completeness

- Interaction of classes must be described in SD
- Methods of CD must be called in SD

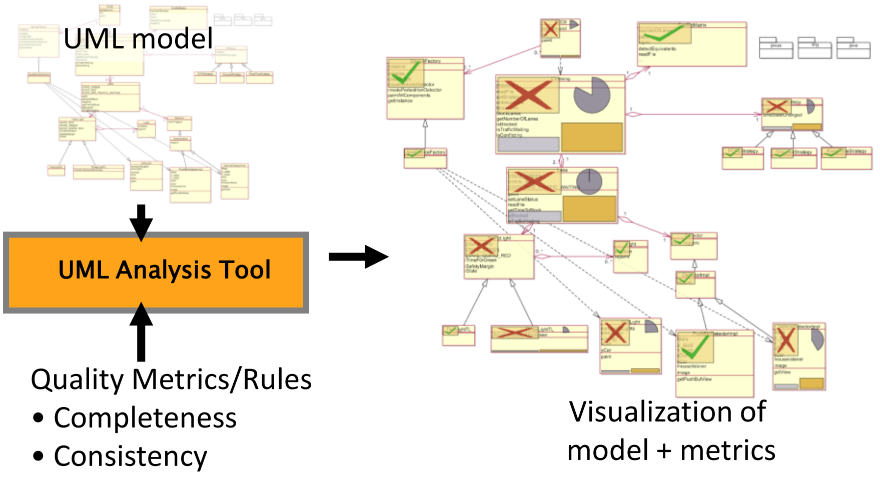
Consistency

- Messages in SD must correspond to method in class diagram

In many cases it can not be automatically determined whether a flaw is an incompleteness or an inconsistency

Automatically Checking Quality of Design

Quality = absence of 'bad things'
such as omissions, spaghetti



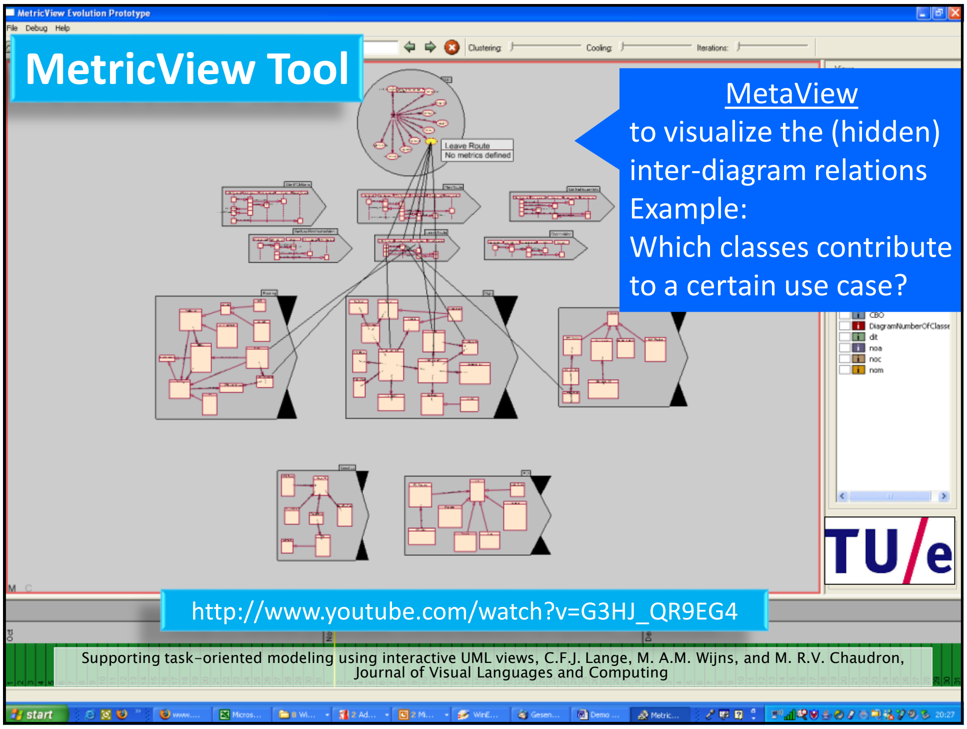
UML model

UML Analysis Tool

Quality Metrics/Rules

- Completeness
- Consistency

Visualization of model + metrics

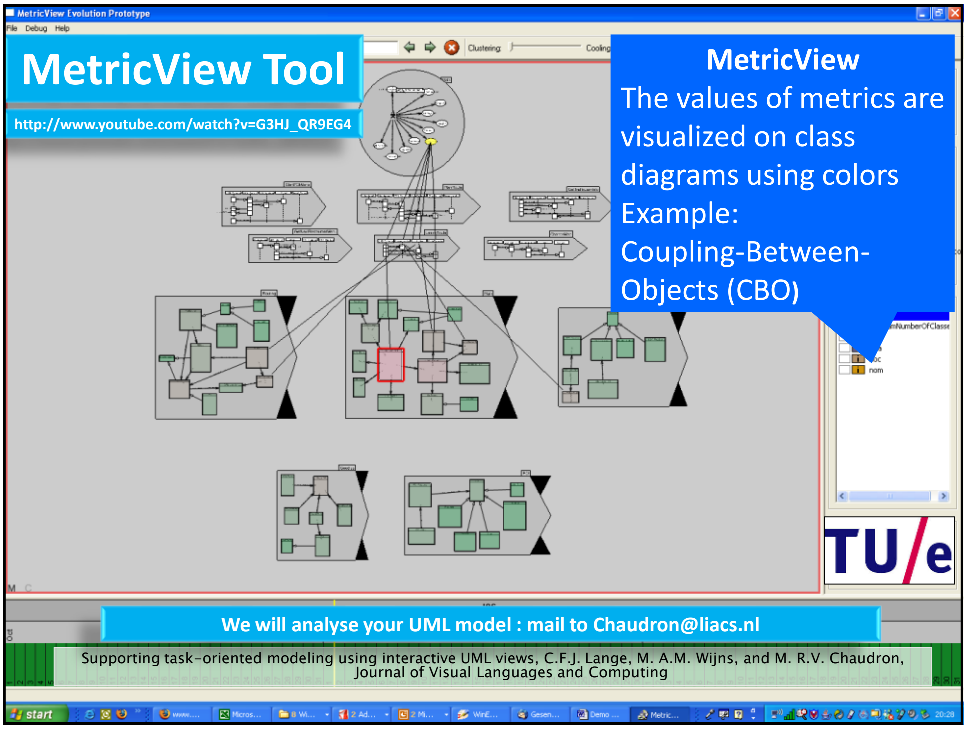


MetricView Tool

MetaView
to visualize the (hidden) inter-diagram relations
Example:
Which classes contribute to a certain use case?

http://www.youtube.com/watch?v=G3HJ_QR9EG4

Supporting task-oriented modeling using interactive UML views, C.F.J. Lange, M. A.M. Wijns, and M. R.V. Chaudron, Journal of Visual Languages and Computing



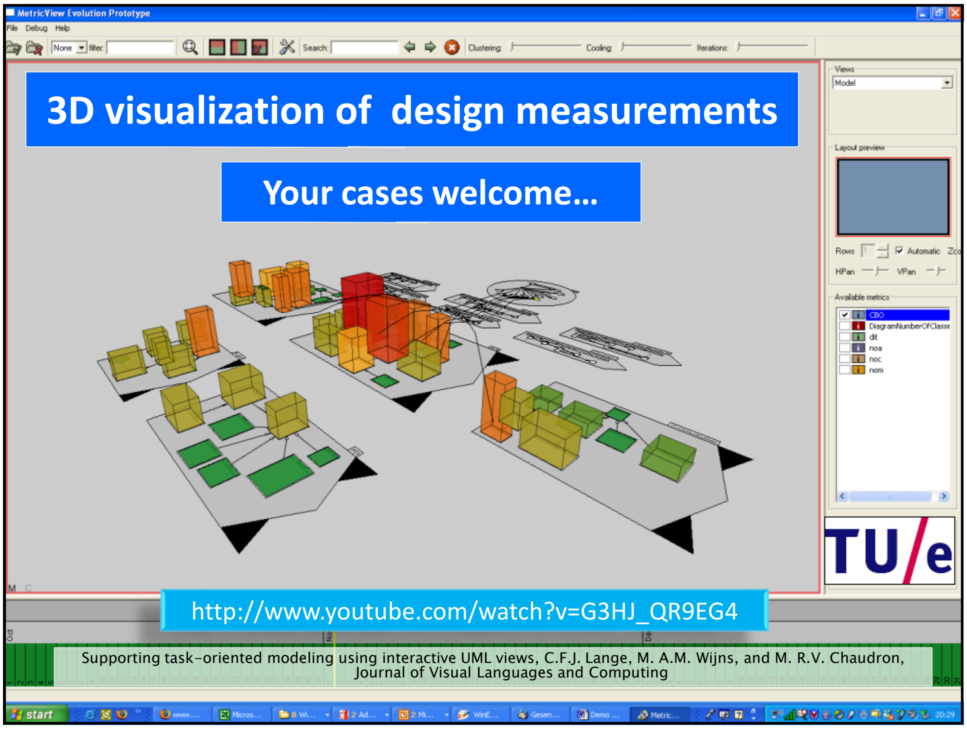
MetricView Tool

http://www.youtube.com/watch?v=G3HJ_QR9EG4

MetricView
The values of metrics are visualized on class diagrams using colors
Example:
Coupling-Between-Objects (CBO)

We will analyse your UML model : mail to Chaudron@liacs.nl

Supporting task-oriented modeling using interactive UML views, C.F.J. Lange, M. A.M. Wijns, and M. R.V. Chaudron, Journal of Visual Languages and Computing



3D visualization of design measurements

Your cases welcome…

http://www.youtube.com/watch?v=G3HJ_QR9EG4

Supporting task-oriented modeling using interactive UML views, C.F.J. Lange, M. A.M. Wijns, and M. R.V. Chaudron, Journal of Visual Languages and Computing

Findings from State of the Practice

UML is used in different ways for different purposes

- Incompleteness
  - Modelers focus on complex and critical parts
- Disproportion
  - Different parts of the system are modeled different in level of quality
- Inconsistency
  - Conflicting information in different views of one model

Quality Assurance for modeling should address these

Findings on Technology Transfer

- There is a gap in transiting prototypes into industrial use
  - No/little credits for academics in building tools (funding, prestige)
- Maintenance:
  - There is no funding for maintaining long-lived software tools
- Development 'end user' Company
  - Interesting idea, but not yet industrial strength
  - This fails to generate necessary feedback!
- Tooling Company:
  - We don't have any company interested yet

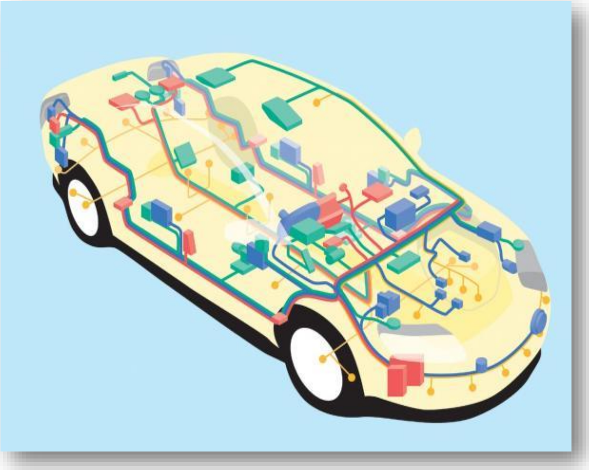
How to organize feedback?

Use of MBSE in Optimization of System Design

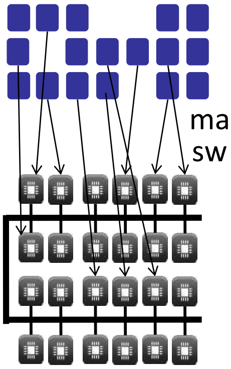
This is the work of Ramin Etemaadi Ph.D.'s research at Leiden University, The Netherlands

https://scholar.google.com/citations?user=EUD3Ek4AAAAJ

Quality Driven Component-based Design



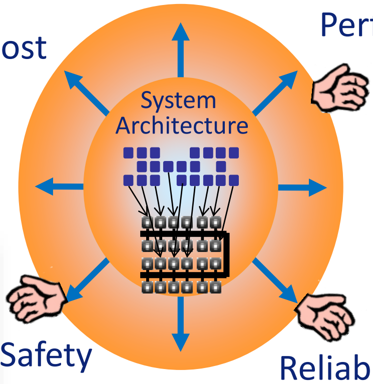
1000 softw. components



100 hardw. components

With 9 types of processors and 6 types of busses, there are 7,346,640,384,000,000 architecture design alternatives

Evaluating Non-Functional Properties of System Architectures



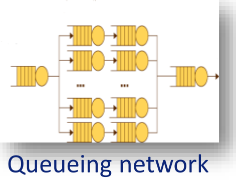
Cost

Performance

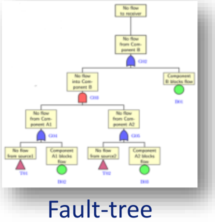
Safety

Power

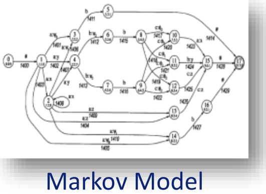
Reliability



Queueing network



Fault-tree



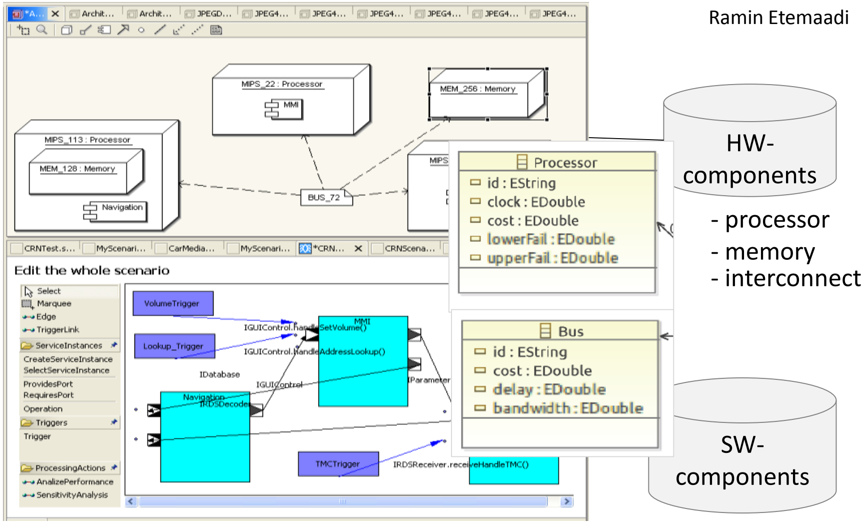
Markov Model

Time-consuming manual work

Limited insight in design space

Modeling & Analysis Tool

with
Egor Bondarev
Peter de With
Ramin Etemaadi



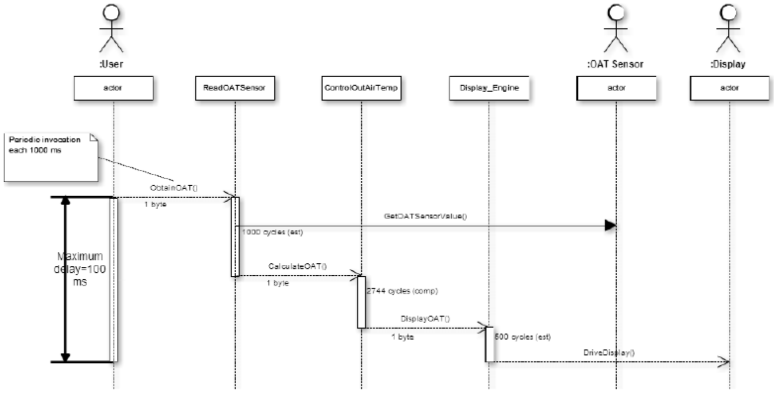
HW-components

- processor
- memory
- interconnect

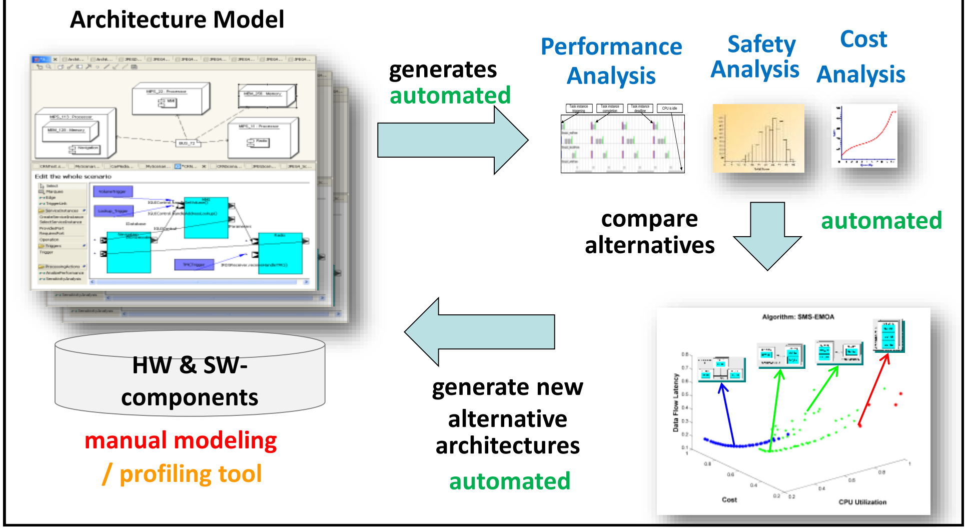
SW-components

Eclipse Plug-in, Java-based, compatible with AADL, EAST-ADL, Auto-SAR

Example Specification of Component Behaviour

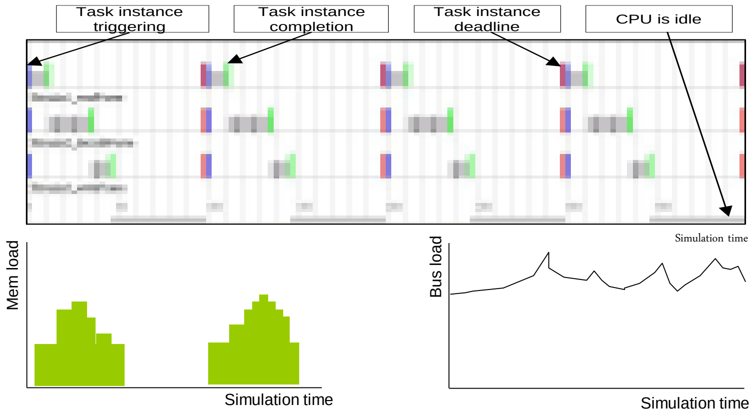


Quality-Driven Architecture Design Method and Tool



Scenario-based Analysis

- Performance or Schedulability analysis are performed with scheduling algorithms (RMA, EDF, CBS)
- Analysis results in task latencies, number of missed deadlines, CPU, memory and bus utilization



Automotive case study

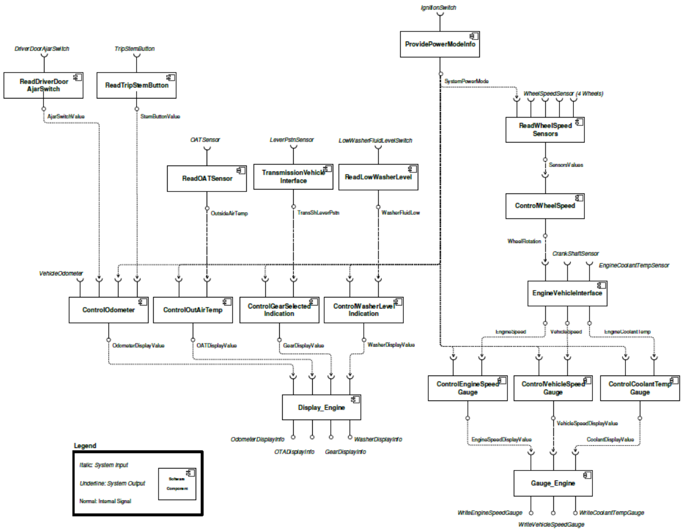
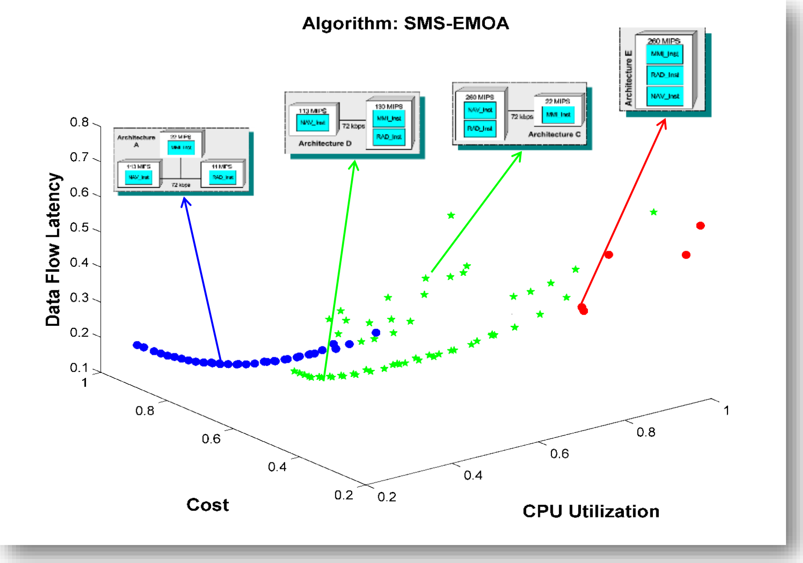


Figure 5.8: *Component diagram of SAAB Instrument Cluster sub-system*



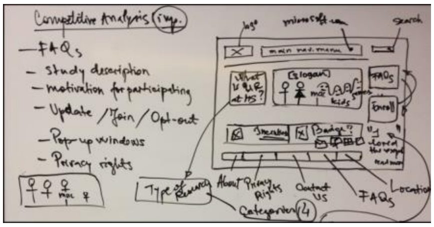
Modeling & Analysis in PMS

Tool development started with interviewing system architects

- They maintain between 3 and 10 critical scenario’s
- They start with estimates, gradually replace with measurements
- Not all sketchy parts are replaced, some stay sketchy.

Modeling & Design

- Notation on whiteboard is very rich
- We are using development tools as enriched typewriters



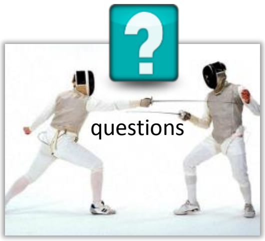
- Modeling = encoding a design in a modelling language
- Designing = making design decisions

Challenge for Modeling tools

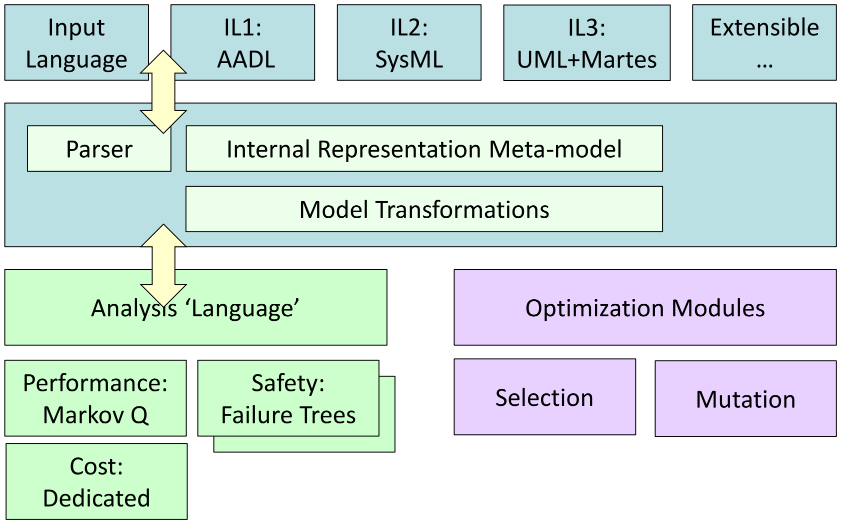
- Understand role of *modeling* in *designing* process
  - Need improved attention to HCI in development tools:
    - task-analysis studies in system design
    - Designers mix rigorous and sketchy modelling
    - Driven by ‘economy’ of design

Concluding Remarks

- There are payoffs for modeling in:
  - improved communication
  - improved quality of design and code
- Modeling is a means to support Design
- Economy of engineering demands a mix of sketchy/informal and rigorous modeling
- Usability/HCI of Development Environments deserves more attention!
  - Task analyses of developers needed



Tooling Ecosystem Platform

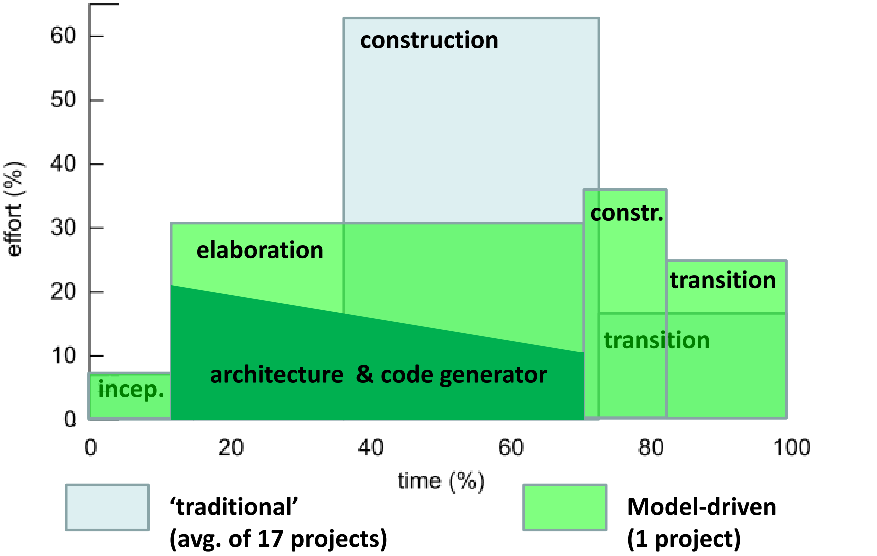


Lessons Learned

- Medical Systems:
  - Lowered level of detail & completeness in favour of economy of modeling
- Consumer Electronics
  - Overhead of modeling became too high due to fast changing platform/technology
  - Successful introduction of MBSE requires:
    - 'champion'
    - Management decision
      - Investment by experts, pay-off by team
      - Lack of agreement/alignment by peers

Impact of MDD on Effort Distribution

as % of total project effort



What to model and how

COST
CoSQ
non-conformance costs
achievement costs
0%
100% (perfect
Quality Metric

- Context dependent
  - Understand your 'receiving party'
  - Ask about receiver expectation and needs
  - Do you share domain knowledge?
  - Agree on conventions
- Pay attention to behaviour modeling
  - Sequence / Activity Diagrams

How much to model?

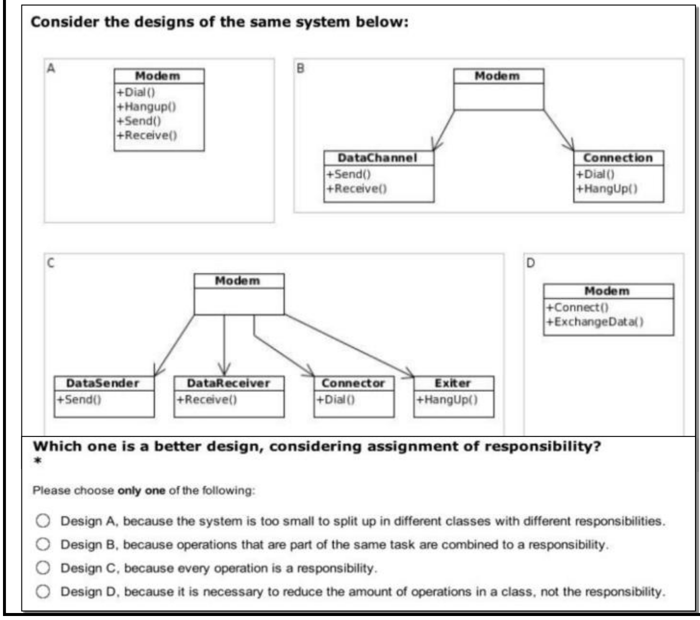
- Design the architecture in “Sprint 0”
- Time-boxed

“For a three week iteration, spend [..] at most one day at the start of the iteration drawing UML for the hard, creative parts”

Craig Larman

“Applying UML and Patterns”, 2009

Online Software Design Principles Test



Consider the designs of the same system below:

Which one is a better design, considering assignment of responsibility?
*

Please choose **only one** of the following:

○ Design A, because the system is too small to split up in different classes with different responsibilities.
○ Design B, because operations that are part of the same task are combined to a responsibility.
○ Design C, because every operation is a responsibility.
○ Design D, because it is necessary to reduce the amount of operations in a class, not the responsibility.

With Dave Stikkolorum (Leiden)

Ongoing development:

- Moving to UML editor in the browser
- Interactive feedback on design

Practical Advice for UML modeling

Low Hanging Fruit
(c) Erin Witzel, 2010

Naming and layout-conventions

The Elements of UML2.0 Style,
Scott Ambler, Cambridge Univ Press, 2005

Traceability

Organize traceability from Use Cases to Sequence diagrams (tool/conventions)

Reviews & Inspections

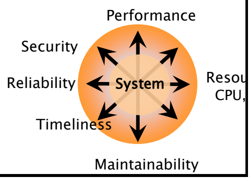
Guidelines by e.g. Shull et.al., Biffl,

Tooling

Version Management - (e.g. CVS, SVN, …)
Metrics : SDMetrics http://www.sdmetrics.com/

Ongoing Ph.D. students

- Dave Stikkolorum – Teaching software design by modeling
- Bilal Karasneh – Towards a repository of UML design models
- Ana Fernandez – Effect of modeling in Software Maintenance
- Truong Ho Quang – Interactive Views for Navigating Complex systems
- Rodi Jolak – Multimodal User Interfaces for Modeling



Needs for Modeling tools

Tools

- Flexibility
- Integratability
  - Open API's
- Scalability
- Performance
- Usability

Companies

- Customize
  - Configure/Tailor
  - In-company standardization

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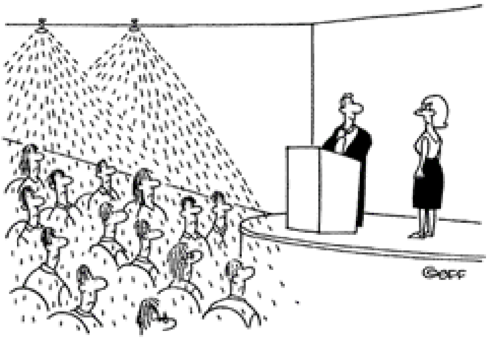


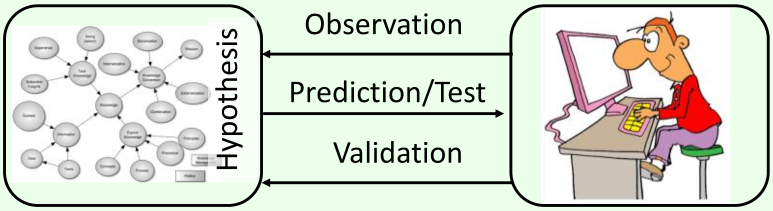
"You're not allowed to use the sprinkler system to keep your audience awake."

Empirical Research

… is a way of gaining knowledge by means of *observation* or *experience*.

Theory
SE body of knowledge

Practice
People/Skills, Processes, Methods, Technology, Artefacts



Observation

Prediction/Test

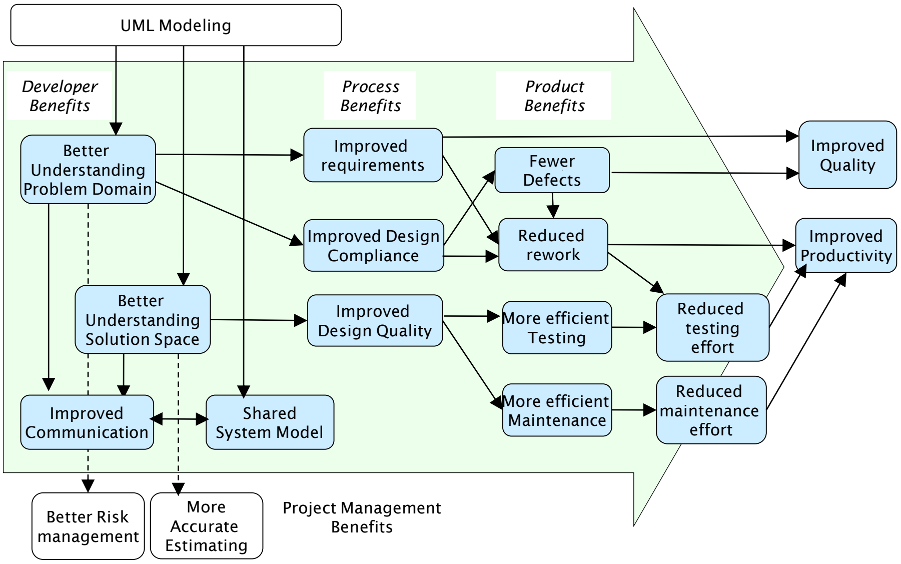
Validation

Hypothesis

Topics: CMM, OO, Agile, MDA, …

Methods: Experiment, Case study, Survey, Project Repositories …

‘Hypothetical’ Benefits of Modeling



UML Modeling

Developer Benefits

Process Benefits

Product Benefits

Better Understanding Problem Domain

Better Understanding Solution Space

Improved Communication

Shared System Model

Improved requirements

Improved Design Compliance

Improved Design Quality

Fewer Defects

Reduced rework

More efficient Testing

More efficient Maintenance

Reduced testing effort

Reduced maintenance effort

Improved Quality

Improved Productivity

Better Risk management

More Accurate Estimating

Project Management Benefits