EmpAnADa Project

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Outline

- EmpAnADa introduction
- Part I
  - Completeness and consistency in detail
- Part II
  - Background
    - UML
    - Empirical research
    - Measurement
  - Directions of the project
    - Metrics
    - Refactoring and changes in an artifact
    - Completeness and Consistency
    - Visualization of Metrics
  - EmpAnADa and LaQuSo

EmpAnADa

- Empirical Analysis of Architecture and Design Quality
- Development of quantitative methods to predict attributes of early artifacts, mainly UML models
  - Quality (maintainability, changeability…)
  - Effort estimation
  - Identification of fault-prone elements
- Empirical studies to
  - Validate methods
  - Investigate UML usage and problems in practice

Part I

Empirical Assessment of Completeness in Industrial UML Designs

Overview of Part I

- Completeness
  - Decomposition
  - Consistency
- Techniques Developed
- Case Studies
- Observations
- Conclusions

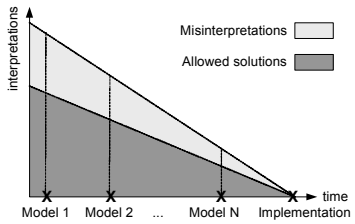
Why Completeness?

- Interviews and surveys investigating industrial use of UML
  - Uncertainty about precision and accuracy of design metrics for prediction of quality attributes
  - Miscommunication
  - Integration problems
  - Uncertainty about completeness of model

Completeness & Consistency

Problem:

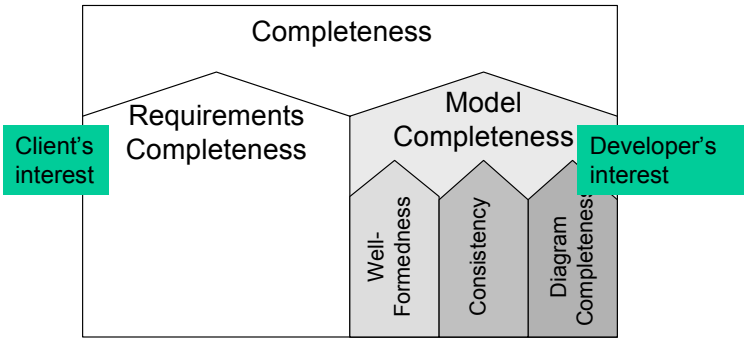
- (Early) models allow several solutions/interpretations (*dark grey*)
  - Source code describes exactly one solution
- Misinterpretations amplified by (*light grey*)
  - lack of completeness
  - presence of conflicts
  - UML specific: overlapping diagram types, no formal semantics, degrees of freedom



Goal:

Investigate the magnitude of completeness of UML models in industrial practice

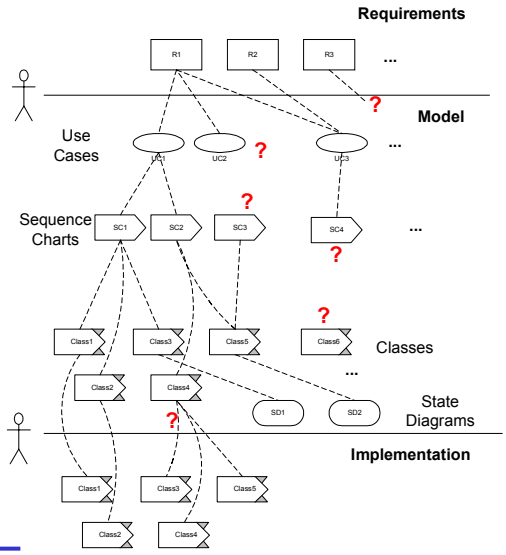
Decomposition of Completeness



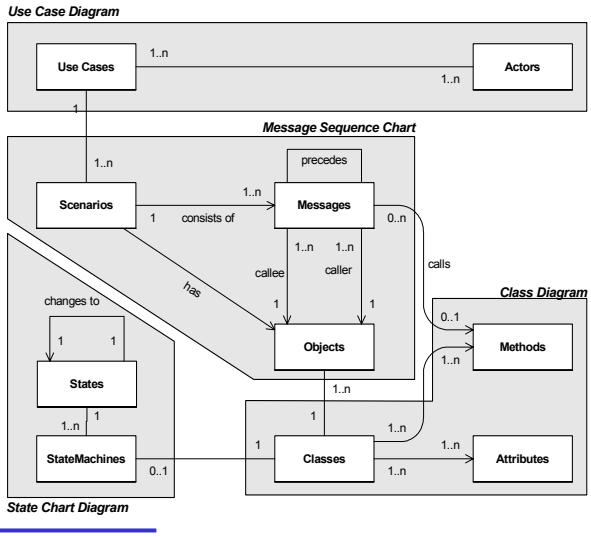
- Well-Formedness:
  - property of individual diagram
- Consistency and Diagram Completeness:
  - relation between different diagrams

Scope of Analysis

- Requirements can be traced across multiple diagram types
- Examples of incompleteness
- Scope of analysis



Relational Meta Model

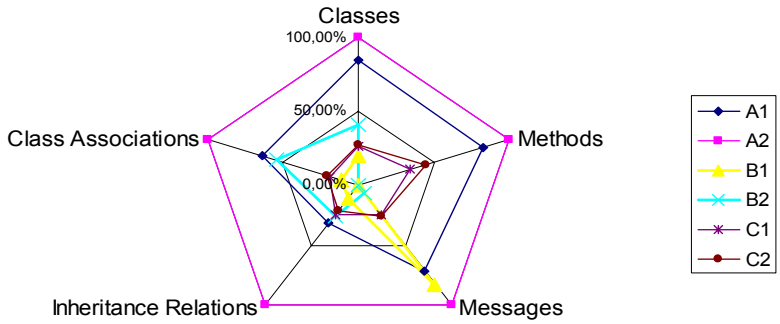


Examples of Rules

- Well-formedness
  - Objects in SD must have a role name
  - Classes must have methods
- Consistency
  - Messages in SD must correspond to method in class diagram
- Completeness
  - Interaction of classes must be described in SD
  - Methods must be called in SD

Rule-checking is implemented in a tool

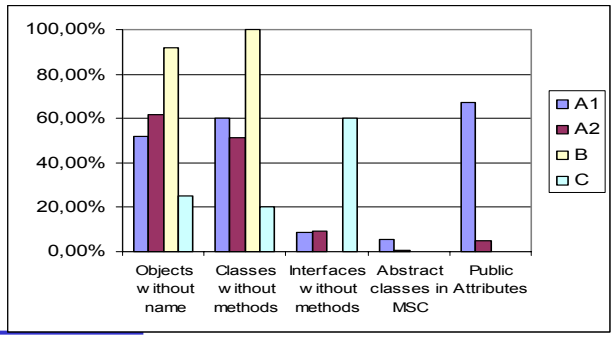
Case Studies



A1, A2	B1, B2	C1, C2
• Image processing	• Embedded Controller	• Embedded Controller
• Subsystems, same version	• Subsequent versions, redesign	• Subsequent version, inspection in between
• 168 classes, 853 messages	• 69 classes, 705 messages	• 46 classes, 219 messages
• >100 man years	• >100 man years	• 1,5 man years
• Real-world	• Real-world	• Post-grad students

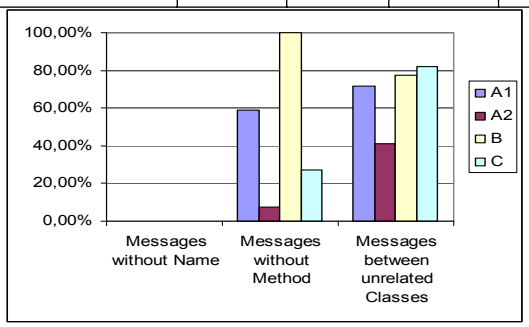
Results: Well-formedness Rules

	A1	*A2*	*B*	*C*
Objects without name	52.00%	61,58%	91.92%	25.24%
Classes without methods	60.19%	51.19%	100.00%	20.00%
Interfaces without methods	8.82%	9.38%	N/A	60.00%
Abstract classes in MSC	5.56%	0.60%	0.00%	0.00%
Public Attributes	67.23%	5.08%	0.00%	0.00%



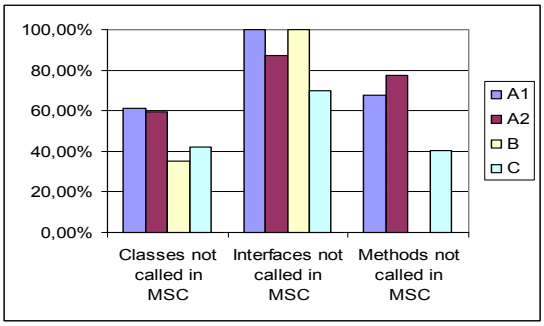
Results: Consistency Rules

	A1	*A2*	*B*	*C*
Messages Without Name	0.00%	0.00%	0.28%	0.00%
Messages without Method	58.73%	7.62%	100.00%	27.14%
Messages between unrelated Classes	71.94%	41.03%	77.73%	81.90%



Results: Completeness Rule

	A1	*A2*	*B*	*C*
Classes not called in MSC	61.11%	59.52%	35.29%	42.22%
Interfaces not called in MSC	100.00%	87.50%	100.00%	70.00%
Methods not called in MSC	67.65%	77.59%	N/A	40.14%



Observations in Case Studies

- Strong differences in the habits of designers
  - even within a single project
  - miscommunication may be reduced by modeling standards
- Degradation between C1 and C2 wrt. SD completeness: rules helped identify missing SD's
- Odd results for SD-rules in B2: identified that wrong version of model was in project repository.
- Case C has best scores: off critical-path project (?)

- Results of assessments can be used for
  → focusing of improvements
  → monitoring progress
  → benchmarking: comparison between different models
  (versions, sub-models, processes)

Contributions & Conclusions

- Industrial-strenght techniques for quantitative assessment of incompletenesses and inconsistencies.
- Case studies provided insight into use of the UML
  - Absolute number of rule violations quite large
  - Industrial projects move into implementation while there are still many incompletenesses
- Incomplete spots identified by tool were confirmed by designers and led to improvements in the design

Future Work

- Which degree of completeness is needed?
  - for high accuracy and precision of estimates
  - to reduce miscommunication
- Do incompleteness and inconsistencies of the model result in flaws in the implementation?
- Can “Modeling standards” (enforced by tooling) improve completeness?

Part II

Background Topics
&
Future Directions

Background - UML

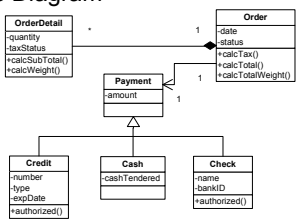
- Unified Modeling Language
  - Booch, Rumbaugh, Jacobson : 1997
- Purpose: visual modelling of different aspects of the system
  - Higher abstraction level than programming
- Diagrams are views on the model
- 9 diagram types

Structural	***Behavioral***
Class diagram	Sequence diagram
Package diagram	Collaboration diagram
Object diagram	State diagram
Use case diagram	Activity diagram
Deployment diagram	

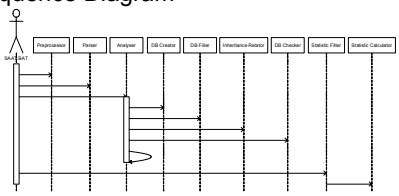
- Extensible by stereotypes, tagged values, meta-model changes
- Lack of formal semantics

Background – UML

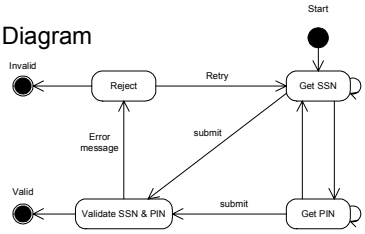
Class Diagram



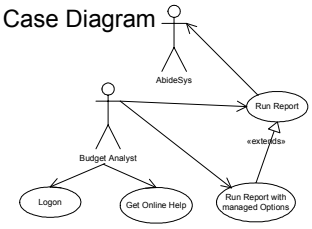
Sequence Diagram



State Diagram



Use Case Diagram

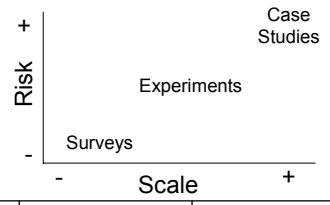


Background – Empirical Research

- SW engineering is cross-disciplinary
  - Technical issues
    - Networks, databases, operating systems…
  - Language issues
    - Syntax, semantics
  - Social issues and psychology
- Why empirical SW engineering research?
  - Quantitative studies give objective and statistically significant results regarding
    - Understanding
    - Controlling
    - Predicting
    - Improving

    } Of the SW Development process
- Empirical strategies
  - Surveys
  - Experiments
  - Case Studies

Background – Empirical Research Strategies



Factor	Survey	Experiment	Case study
Execution control	No	Yes	No
Measurement control	No	Yes	Yes
Investigation cost	Low	High	Medium
Ease of replication	High	High	Low

Empirical Research in EmpAnADa

- Survey
  - Web-questionnaire about UML usage
- Experiment
  - Classroom experiment is planned
- Case Studies
  - Always looking for case studies
  - Currently contacts to
    - Philips (PMS, Optical Storage)
    - Siemens Corporate Research
    - LogicaCMG / Thales
    - Oce
    - CGE&Y
    - CBS

Background - Measurement

- "*Measurement is a mapping from the empirical world to the formal, relational world*" (Fenton)
- Types of metrics
  - Product
    - Lines of Code (LOC), Depth of Inheritance, number of defects…
  - Process
    - Cost per number of errors found, coverage of a test…
  - Resource
    - Team size, experience of staff, age of staff…
- Most product metrics research is about finished products

Measurement in EmpAnADa

- Metrics are objective and automatically collectable
- Implementation metrics
  - Measure the exact product
  - Rather late
- Design Metrics
  - Early feedback in the analysis and design phase
  - Not all implementation metrics can be used
  - Opportunity for new metrics (multi-view)

Measurement in EmpAnADa II

- Relation between design metrics and properties of product
  - Quality properties
    - Maintainability
    - Comprehensibility
    - Changeability
    - …
  - Defects
    - Finding relationships between metrics and test data, bugreports
    - Metrics to predict fault-prone classes
  - Prediction of process data
    - Development effort
    - Resource usage
- Design metrics as predictions: Accuracy and Precision
  - Depend on
    - Correspondence of model and source code
    - Completeness and Consistency of model

Completeness and Consistency

- Define completeness and consistency for UML models
- Assess the magnitude of violations in industrial practice
- What are the effects of C&C violations for the implementation?
- Which degree of C&C is needed for precise and accurate predictions based on UML models?

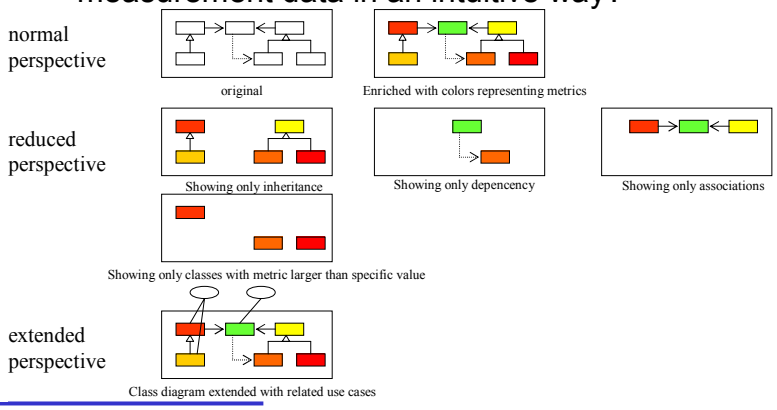
Part I

Refactoring and Evolution

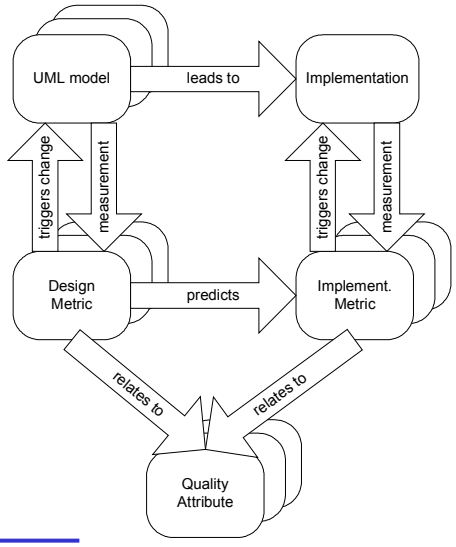
- Refactoring:
  - "*Changing a SW system to improve its structure without altering the external behavior*" (Fowler)
  - Most literature considers source code refactorings
  - Approaches:
    - Defining higher level refactorings (architecture, design)
    - Investigating the role of metrics as "design smells"
- Evolution
  - How does the quality of designs change over subsequent versions?

Visualization of Metrics and Artifacts

- For large systems metrics tools produce large amount of data
- Which techniques are useful to present the measurement data in an intuitive way?

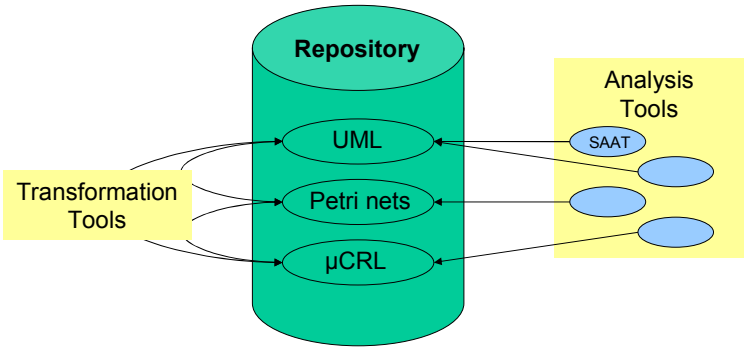


Summary of topics



Activity within LaQuSo

- Architecture Repository Group
  - Developing a repository to store SW architectures and designs in different formalisms



Discussion

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