Using Model Scoping with Expected Model Elements to Support Software Model Inspections: Results of a Controlled Experiment

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Motivation & Key Questions

Motivation and Application Context

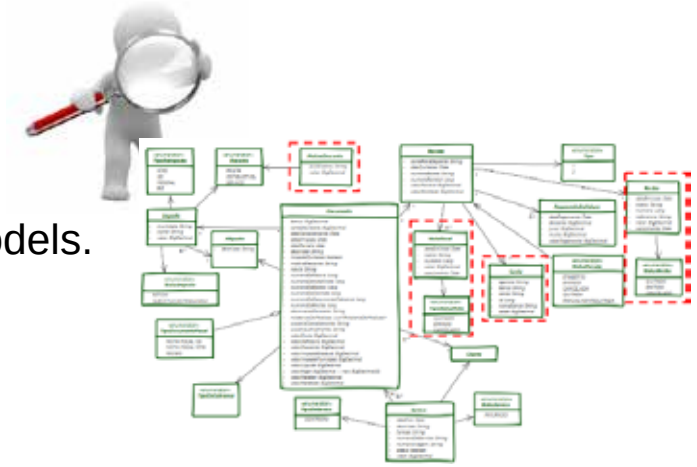


Fig. Context of Model Inspection.

- Traditional Software Inspection to identify defects in software engineering models.
- Limitations for Large-scale software engineering models.
- Expected Model Elements (EMEs) and Model Scoping (remove unrelated parts).

Key Question

- How to improve defect detection performance for large-scale engineering models with model scoping?

Goal of this presentation

- Report on a controlled experiment with students using real industrial artifacts aiming to understand the impact of model scoping and model inspection effectiveness/efficiency.
- Inspection of UML class diagrams using Model Scoping with EMEs compared to traditional Software Inspection (without model scoping and EMEs).

Software Model Inspections

- Software Inspection* is a well-established formal approach for efficient defect detection in early software development phases, e.g., during software design.
- Model Scoping is generic and not restricted to a particular type of requirements.

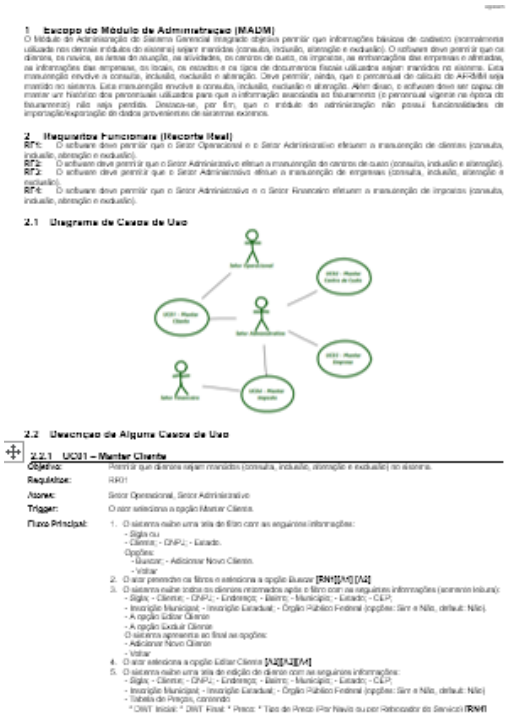


Fig. Requirements Specification.

Does the model completely and correctly represent the specification?

Are there defects in the scoped model?

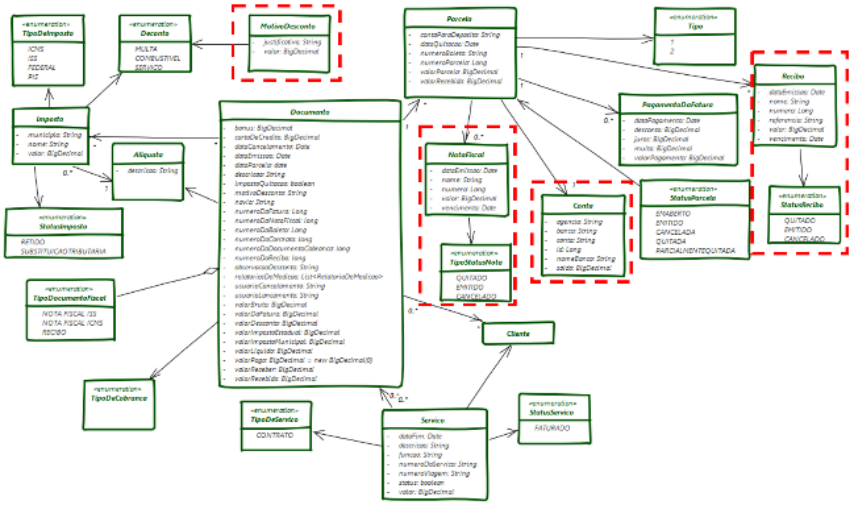


Fig. Cut-outs during Model Scoping (dashed rectangles).

* Fagan ME, 1976, Design and code inspections to reduce errors in program development, IBM Systems Journal, 15(7): 182-211

Goal & Research Question

Based on the Goal-Question Metric (GQM)* approach:

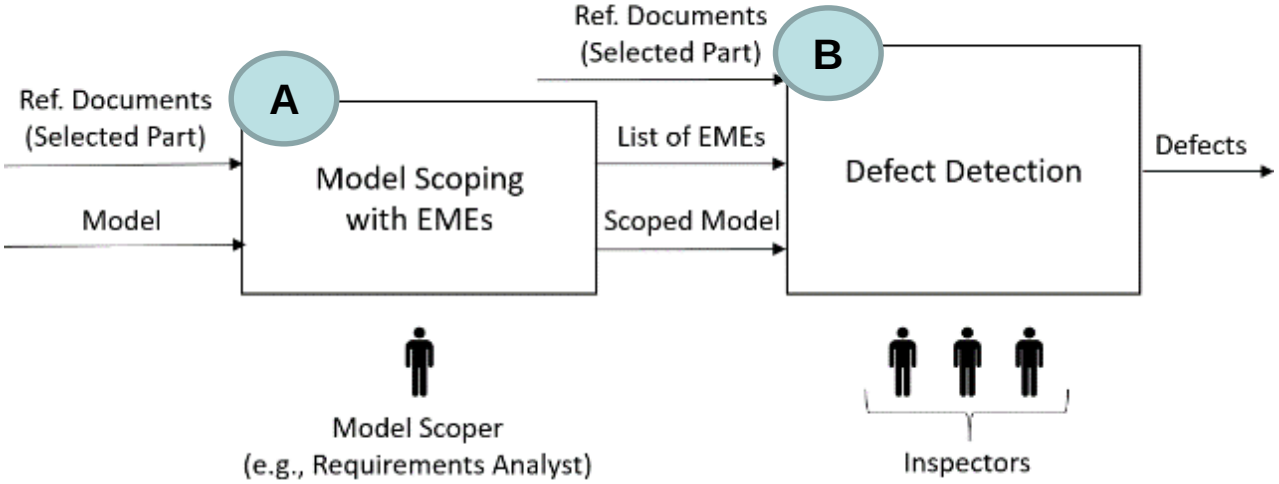
Analyze	the inspection of UML class diagrams using *Model Scoping with EMEs*
for the purpose of	characterization
with respect to	inspection effectiveness & efficiency
from the point of view of	the information systems researcher
in the context of	UML class diagram inspection based on a valid functional specification, conducted by novice inspectors, when compared to not using *Model Scoping with EMEs* .

Research Question:

- How could a Process for Model Scoping based on Expected Model Elements as foundation for Defect Detection be implemented?
- What is the impact of Model Scoping with EMEs on Software Inspection performance, i.e., effectiveness and efficiency?

*van Solingen R, Basili V, Caldiera G, Rombach HD, 2002, Goal Question Metric (GQM) Approach, In: *Encyclopedia of Software Engineering*

Model Scoping and Defect Detection Process with EMEs



Step A: Model Scoping with EMEs approach includes:

1. Define the types of EMEs, e.g., for UML Class Diagrams: classes, attributes, relations.
2. Identify list of relevant EMEs based on the selected part of the reference document.
3. Scope the model by removing model elements that are not in the list/scope of EMEs.

Step B: Defect Detection based on EMEs and the Scoped Reference Document:

1. Appearance: Is the EME represented in the model?
2. Correctness: Is the EME modeled correctly?

à Foundation for Identifying and Reporting Defects.

Empirical Study
Approach and Study Design

- **Controlled Experiment in class-room settings.**
- **Comparison of Defect Detection Approaches**
  - Traditional (ad-hoc) inspection approach without any specific reading technique.
  - With / Without Model Scopes based on EMEs.

	Exercise A - step one -	Exercise B - step two -
Group 1	*Ad-hoc*	*Model Scoping*
Group 2	*Model Scoping*	*Ad-hoc*

- **Cross-Over Design with 2 Groups and 2 Exercises.**
  - Group 1: Ad-hoc without Model Scopes à Ad-hoc with Model Scopes.
  - Group 2: Ad-hoc with Model Scopes à Ad-hoc without Model Scopes.

- **Study Schedule (3 days)**
  - Day 1: Preparation - Consent Form and Characterization Questionnaire.
  - Day 2: Training and 1st part of the experiment.
    - Tutorial & Training (15 min).
    - Execution of Exercise A with focus on four simple use cases (75 min).
  - Day 3: Execution of Exercise B with focus on two complex use cases (75 min).

Study Design
Application Domain and Material

- **Application Domain**
  - Integrated administration system with 2 modules including
    - Simple Administrative Tasks (4 Tasks, Exercise A)
      e.g., maintaining company and customer data, tax information, and cost centers.
    - Complex Billing Tasks (2 Tasks, Exercise B)
      e.g., registering invoices for provided services; registering payments for invoices.

- **Inspection Artifacts**
  - Overview description; List of functional requirements; use case diagrams; and use case descriptions.
  - Class diagram: 19 classes (full UML diagram) vs. 12 classes (scoped UML diagram) for the selected model scope.

- **Questionnaires**
  - Consent form and participant characterization (participant background).
  - Qualitative Feedback following the Technology Acceptance Method (TAM)*.

*Turner M, Kitchenham B, Brereton P, 2010, Does the technology acceptance model predict actual use? A systematic literature review, Information and Software Technology, vol, 52: 463-479

Study Design
Defects and Participants

- **Requirements Specification was considered to be correct.**

- **Seeded Defects in the Class Diagram**
  - Overall 28 seeded defects.
  - Different defect types: ambiguity, incorrect facts, omission, extraneous information, (and inconsistencies*).
  - 7 typical defects per defect type at different severity levels.

Fig. Example: Qualification of 2nd experiment run.

- **Participants**
  - Overall 40 Participants in two experiment runs (32 + 8).
  - Exact replication in the 2nd run.
  - Randomized and balanced assignment to experiment groups.
  - Background characterization to capture experience on (a) Software Development, (b) UML Modeling, and (c) Software Inspection.

Group	ID	Software Development	UML Models	Software Inspection
1	P33	H	H	L
	P34	L	H	L
	P35	M	M	L
	P36	H	H	M
2	P37	H	H	M
	P38	H	H	L
	P39	L	H	L
	P40	M	H	L

* No seeded defects for inconsistencies

Study Design
Variables and Hypothesis

Variables

- Independent Variables:
  - Defect Detection approach applied, participant qualification.
- Dependent Variables:
  - Effectiveness: Share of identified (true) defects and seeded defects.
  - Efficiency: Real defects per time interval (e.g., per hour).

Hypothesis:

- H01: No difference regarding defect detection effectiveness when inspecting UML class diagrams with or without using *Model Scoping with EMEs*.
- H02: No difference regarding defect detection efficiency when inspecting UML class diagrams with or without using *Model Scoping with EMEs*.

Statistical Evaluation

- Descriptive Statistics, Hypothesis testing based on Mann-Whitney Test at 90%*.

*Dybå T, Kampenes VB, Sjøberg DIK, 2006, A systematic review of statistical power in Software Engineering experiments, Information and Software Technology 48 (8):745-755.

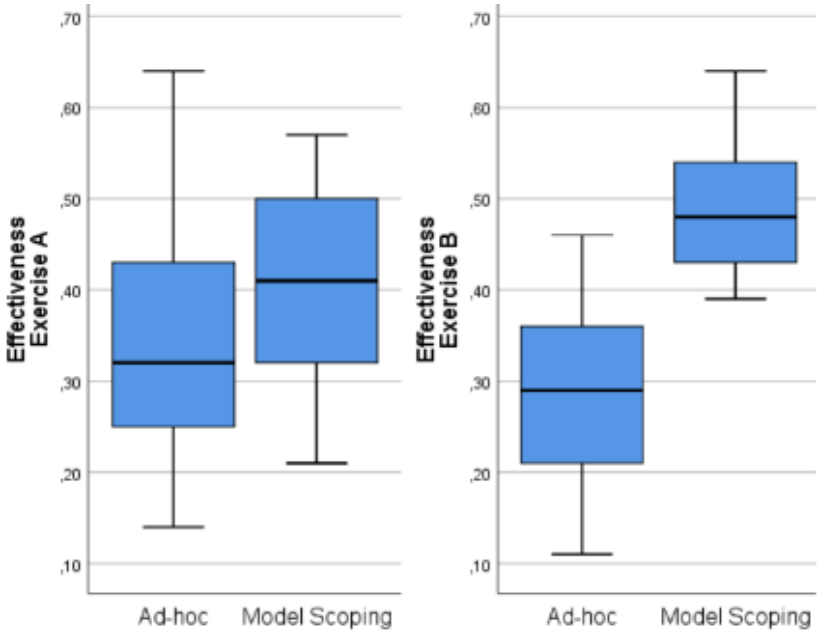
Results

Defect Detection Effectiveness

- **Effectiveness**:
  - True Defects Found / Seeded Defects.

- **Hypothesis Testing**
  - Mann-Whitney-Test (90%).
  - p-value: 0.075 (s) for Exercise A.
  - P-value: 0.001 (s) for Exercise B.

- Model Scoping Groups with EME guidance were significant more effective in both trials (exercise A and B).



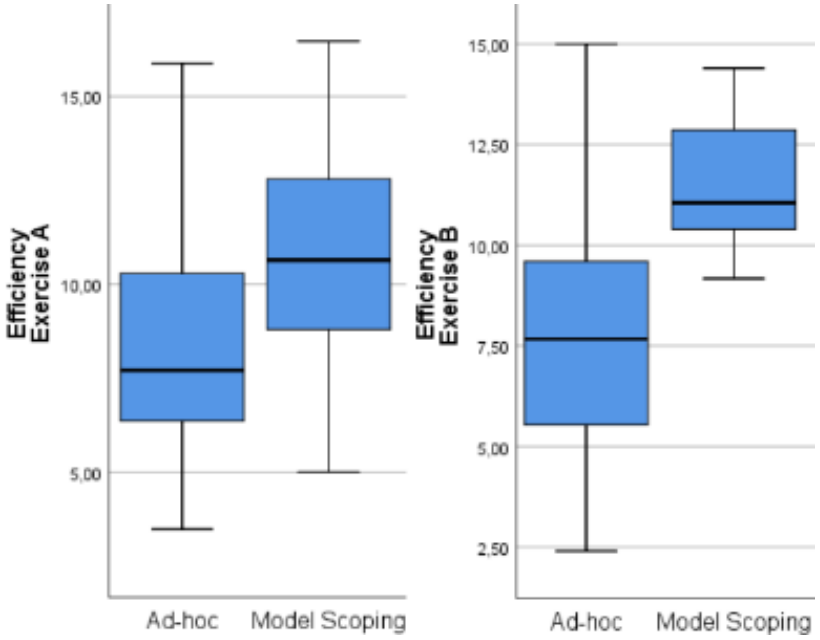
Effectiveness	Exercise A (Simple)		Exercise B (Complex)	
	Ad-Hoc	Model-Scoping	Ad-Hoc	Model-Scoping
MEAN	0,3	0,4	0,3	0,5
SD	0,13	0,10	0,10	0,07

- **Higher Effectiveness for Defect Detection for Model Scoping Groups**
  à H01 must be rejected.

Results
Defect Detection Efficiency

- **Efficiency**:
  - Number of identified true defects per time interval (i.e., per hour).

- **Hypothesis Testing**
  - Mann-Whitney-Test (90%)
  - p-value: 0.025 (s) for Exercise A
  - p-value: 0.001 (s) for Exercise B



- Model Scoping Groups with EMEs guidance were significant more efficient in both trials (exercise A and B).

Efficiency	Exercise A (Simple)		Exercise B (Complex)	
	Ad-Hoc	Model-Scoping	Ad-Hoc	Model-Scoping
MEAN	8,6	10,6	7,4	11,5
SD	3,15	2,80	3,10	1,73

- **Higher Defect Detection Efficiency for Model Scoping Groups**
  à H02 must be rejected.

Discussion & Threats to Validity

How to improve defect detection performance for large-scale engineering models with model scoping?

- In the study context the Model Scoping and Defect Detection Process
  - supported defect detection performance well, i.e., significantly improved defect detection effectiveness and efficiency.
- Model Scopes and guidance by EMEs (based on feedback questionnaire):
  - was perceived useful by participants.
  - decreased task complexity based subjective participant assessment.
  - Guidance with EMEs also supports defect detection.

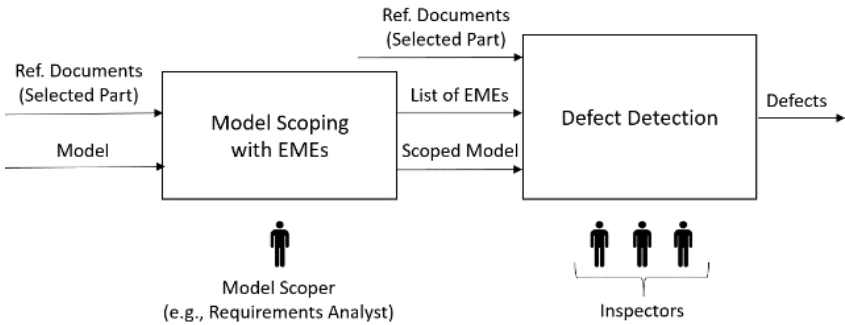
Threats to validity

- Internal: individual inspection of participants (no communication allowed), review of the experimental material and pilot test runs of the experiment.
- External: focus on real-world artifacts (from an individual organization); students act as participants (we captured their experience prior to the study).
- Construct: we applied a cross-over design to isolate learning effects; defects were seeded according to experiences of researchers and practitioners.
- Conclusion: We removed outliers and applied statistical tests, proven in similar contexts.

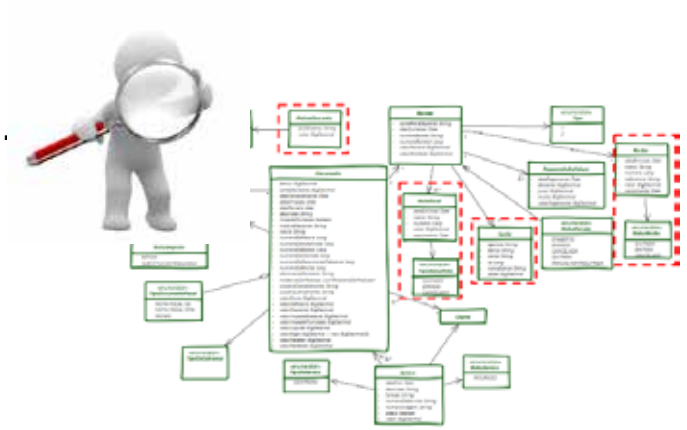
Summary and Future Work

Summary

- The Model Scoping and Defect Detection Process with EMEs consist of a
  - Model Scoping and
  - Defect Detection Process Step.



- Model Scoping can act as filter or view to focus on relevant model elements.
- Support for inspecting Large-Scale Engineering Models.
- Promising results in the study context.



Future Work

- Further investigations to precisely estimate in which cases Model Scoping with EMEs would be (most) worthwhile the upfront investment.
- Replicating the reported experiment on Model Scoping with EMEs, including other engineering model types in different contexts, to reinforce experimental evidence and improve external validity.

Thank you ...

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