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

♭ 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.

Does the model completely and correctly represent the specification?

Are there defects in the scoped model?

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* 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*?

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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?
   † 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.
- Cross-Over Design with 2 Groups and 2 Exercises.
  - Group 1: Ad-hoc without Model Scopes ‡ Ad-hoc with Model Scopes.
  - Group 2: Ad-hoc with Model Scopes ‡ 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)*.

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.

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.

* No seeded defects for inconsistencies

<table>
<thead>
<tr>
<th>Group</th>
<th>ID</th>
<th>Software Development</th>
<th>UML Models</th>
<th>Software Inspection</th>
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<td>L</td>
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</table>

Fig. Example: Qualification of 2nd experiment run.
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%*.

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).

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<th>Exercise B (Complex)</th>
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<td>SD</td>
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</table>

Higher Effectiveness for Defect Detection for Model Scoping Groups
‡ 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).

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Higher Defect Detection Efficiency for Model Scoping Groups
† H02 must be rejected.
Discussion & Threats to Validity

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

β 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.

β 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

β Internal: individual inspection of participants (no communication allowed), review of the experimental material and pilot test runs of the experiment.

β External: focus on real-world artifacts (from an individual organization); students act as participants (we captured their experience prior to the study).

β Construct: we applied a cross-over design to isolate learning effects; defects were seeded according to experiences of researchers and practitioners.

β 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.
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