How and Why is Change Modeled? – A Scoping Literature Review

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KASTEL-DSiS
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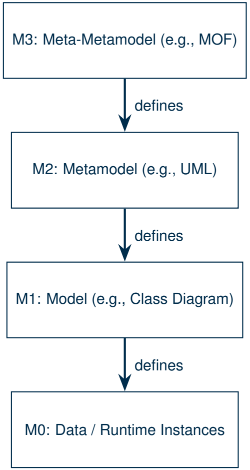
Introduction

Change

- Change is central to development in computer science [1]
- ‘*The only constant is change.*’ — Heraclitus[a]

[a] Attributed to Heraclitus, based on fragments of his writings. See: https://www.reference.com/world-view/said-only-thing-constant-change-d50c0532e714e12b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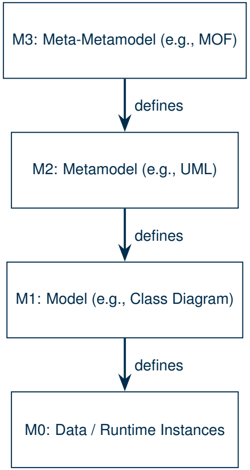
- Concrete artifacts: models and metamodels
- Shared conceptual core of change across domains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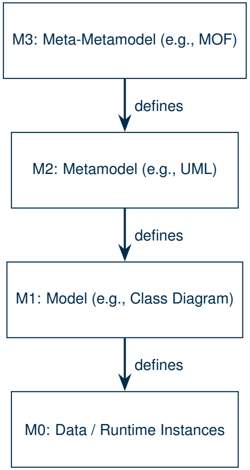
Scope

Model-Based Engineering

Excludes other dimensions, e.g., organizational change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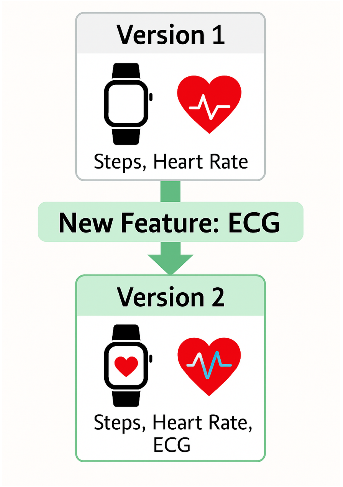
Motivation

Why Model Change?

Isn’t dealing with change enough?



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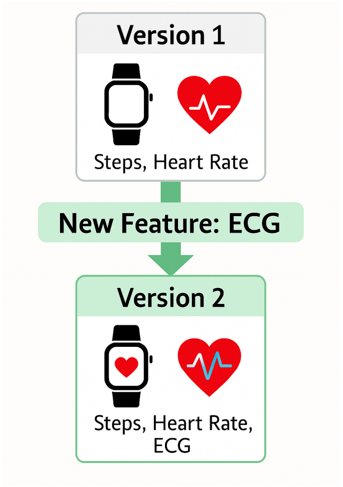

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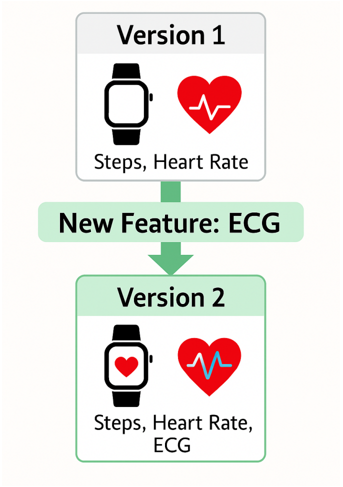
Rationale

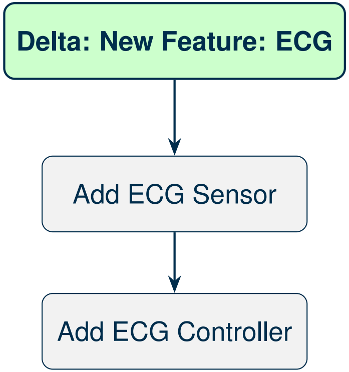
- Models evolve over time
- Changes must be tracked and understood
- States alone may lose information [1]
- Example: rename vs delete + re-add



Delta Concept

What is a Delta?

- Delta, i.e., description of change
- Artifact structure affects how change is defined and modeled



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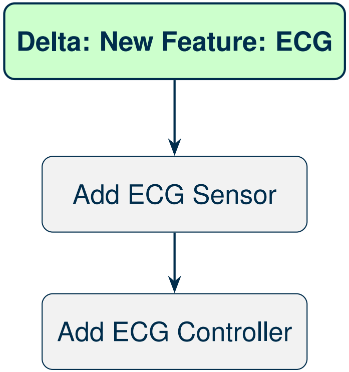
Semantics of a Delta

- Artifacts range from semantically meaningful (metamodels) to syntactic (e.g., Git blobs)
- Metamodel-level changes can be interpreted as domain-specific or domain-agnostic



Scoping Literature Review

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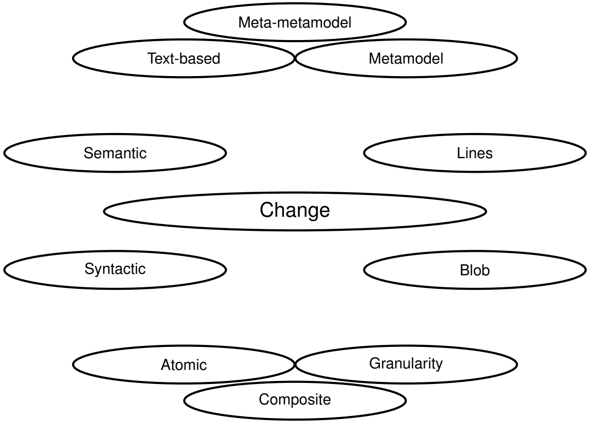
This Review

- Based on Munn et al.'s guidelines. [2]
- Inclusion: MDE context, concept & definition of change, model/metamodel focus
- Exclusion: Non-English, not peer-reviewed, no full text
- Sources: Scopus, IEEE, ACM, Google Scholar
- Final set: 41 core papers selected

RQ1: How is Change Modeled?

Modeling Change

- Change defined by consequence, i.e., difference before and after
- Requires structured artifacts to assess and model change
- Changes are modeled as modifications to models and metamodels



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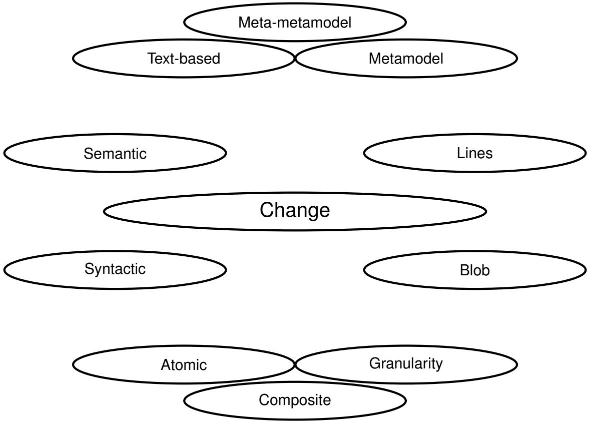
Structure

- Structure enables modeling at different abstraction levels
- Granularity ranges from blackbox blobs to, e.g., line-based divisions



RQ2: Purpose of Change Metamodel

Why Purpose Matters

- Purpose defines goals and requirements of change metamodels
- Different stakeholders — different motivations for change
- Use cases influence design priorities, e.g., completeness or performance

Describe Changes

Analyze Evolution

Enable Automation

Support Consistency

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Purpose and Trade-offs

- Supports versioning, synchronization, transformation
- Different purposes imply different requirements
- Traceability vs. performance trade-offs
- Stakeholder diversity affects modeling needs

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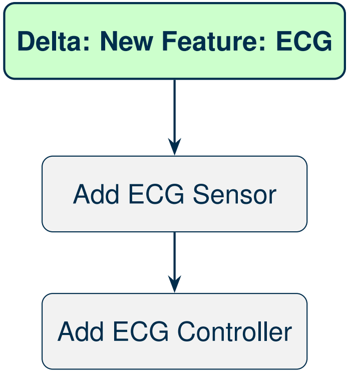
RQ3: Atomic and Composite Changes

Modeling Change Types

- Atomic: complete coverage of change types
- Enables rollback, traceability, automation



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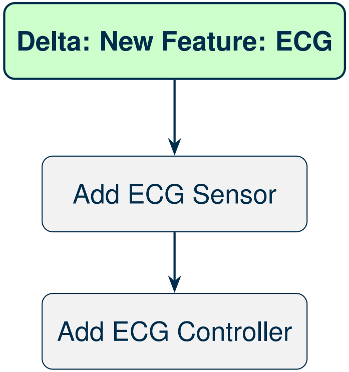
Composite Changes

- Composite changes, i.e., finite atomic groupings, but in-complete in regard to possible changes
- Composite: user intent [3], productivity, understanding

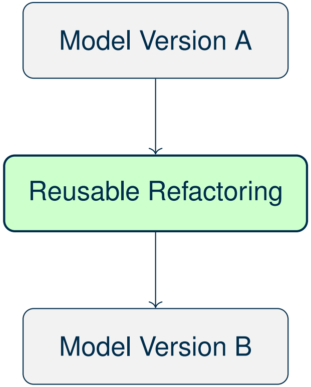


Example: EDelta: Reusable Metamodel Refactorings [4]

EDelta Overview

- Supports atomic and composite metamodel changes
- Enables reusable refactoring catalog

- Built on Xtext and EMF
- Purpose: enable safe and automated evolution of metamodels

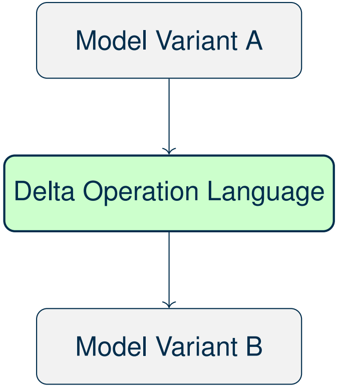


Example: Delta Operation Language [5]

Delta Operations

- Software Product Line Engineering
- Metamodel-independent approach, deriving metamodel-specific change metamodels

- Models differences via delta operations
- Supports complete atomic change modeling
- Purpose: Enables product derivation with deltas

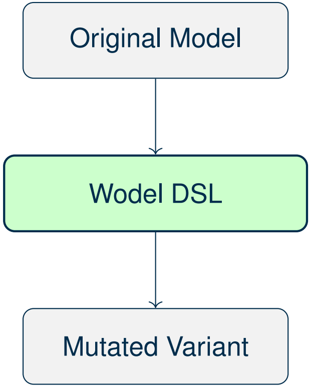


Example: Wodel – DSL for Model Mutation [6]

Mutation DSL

- Domain-independent DSL for model mutation
- Supports atomic and composite changes

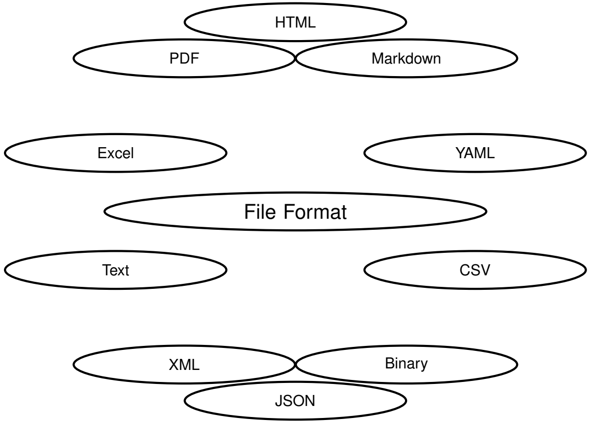
- Enables programmatic generation of model variants
- Purpose: testing, variant creation, mutation analysis



Artifact Structure

Structure

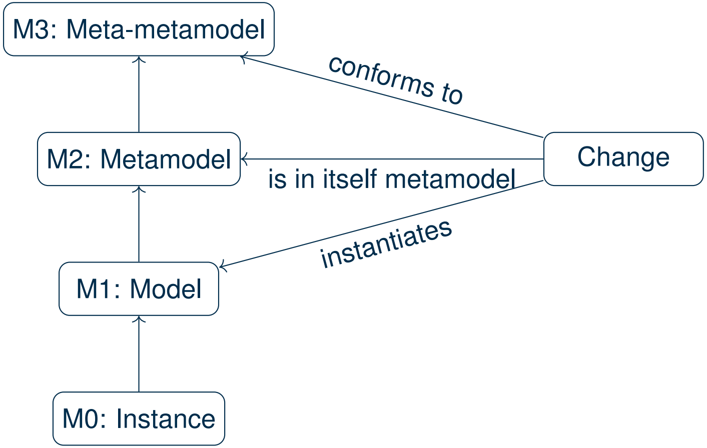
- Structure can be semantic or syntactic
- Metamodels: domain-specific, strict structure
- Text-based artifacts: less struc-tured
- Structure affects change model-ing capability



Meta-Metamodel Level

Cross-Domain Flexibility

- Changes at meta-metamodel level are domain-agnostic
- Metamodel defines domain-specific semantics
- Enables reuse across domains
- Supports flexible change modeling



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Structural Scope

- Artifacts range from blackbox blobs to structured models [7]
- More structure enables finer change modeling, but reduces generality [8]

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Metamodeling Approaches

- Most approaches build on EMF [9], with exceptions [10, 11, 12, 13, 14]
- Change metamodels defined at metamodel or meta-metamodel level [15, 16, 17]
- Parametrized metamodels balance generality and specificity [16]

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Advanced Concepts

- Semantic vs. syntactic dimensions influence applicability [18]
- Terminology varies: change, delta, operation, event, mutation [19, 6]

RQ2: What is the Purpose of the Change Metamodel?

Describing and Reusing Change

- Central purpose: describe modifications between model versions [20, 21, 22, 5]
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Versioning and Collaboration

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- Support for collaborative modeling, conflict management, and live modeling [27, 28, 11, 12, 13, 14]

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Consistency and Evolution

- Enables consistency preservation and model repair [29, 30, 16, 31]
- Supports co-evolution, variant derivation, and semantic reasoning [32, 33, 34, 17, 18]

RQ3: To What Extent Can Atomic and Composite Changes Be Modeled?

Atomic Changes

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Granularity and Completeness

- Granularity affects understandability and correctness of change modeling
- Incomplete metamodels or heuristic-based grouping may lead to erroneous co-evolution [16]

Discussion: Designing and Applying Change Metamodels

Metamodel Selection

- Choose between existing, derived, or custom metamodels based on purpose and domain [35]
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Combining Metamodels

- Use multiple metamodels for different tasks (e.g., consistency vs. user display)
- Annotate changes with intent or standards [3]

Conclusion

Key Insights

- Presented scoping literature review change metamodels
- Addressed three RQ modeling, purpose, and granularity
- Identified diverse approaches in change modeling
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Future Work

- Build a systematic literature review based on this study
- Explore combining metamodels for complex use cases
- Align abstraction levels with user needs and consistency mechanisms

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