# Model Consistency ensured by Metamodel Integration MoConseMI

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# Motivation

- various Artifacts in Software Development:
  - Diagrams, DSLs, Tools, ...
  - Artifacts are technically separated
  - Artifacts are interrelated regarding content
- Ensure Consistency between Artifacts automatically

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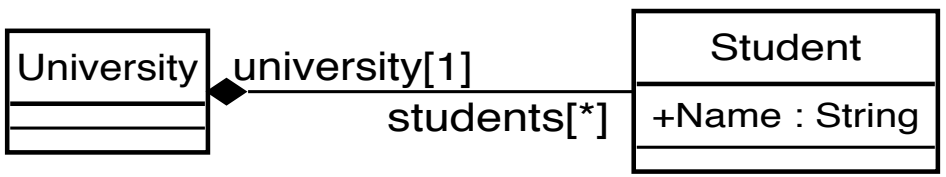

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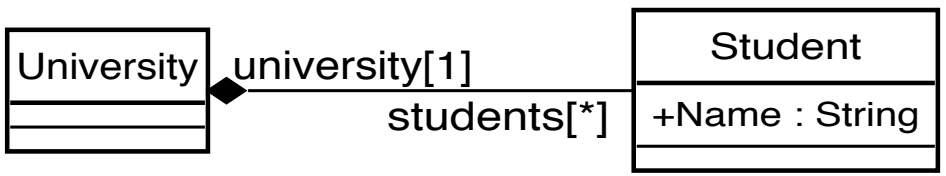


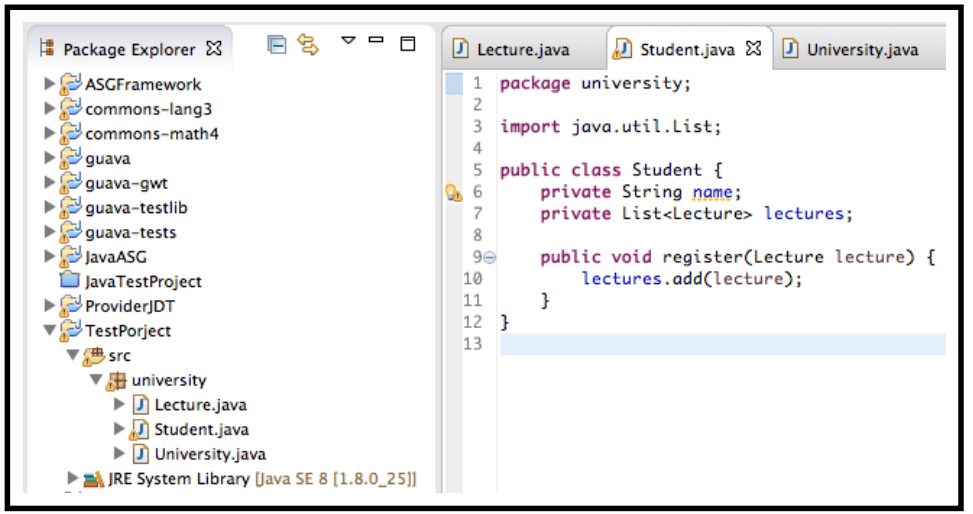

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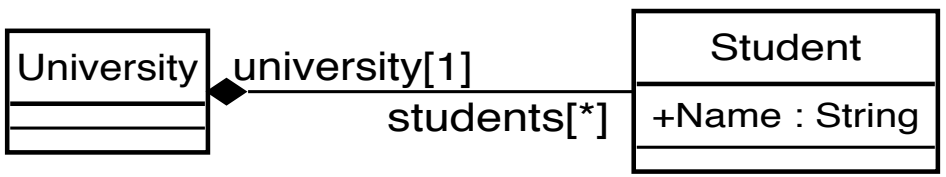


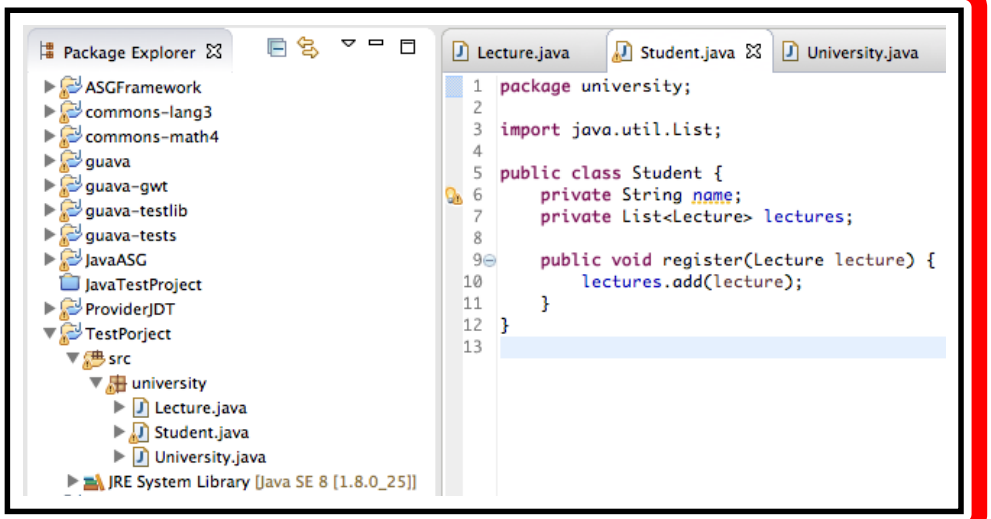

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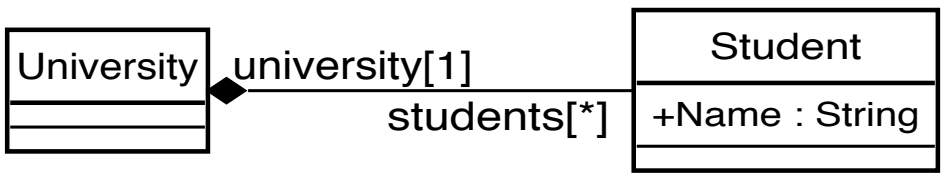


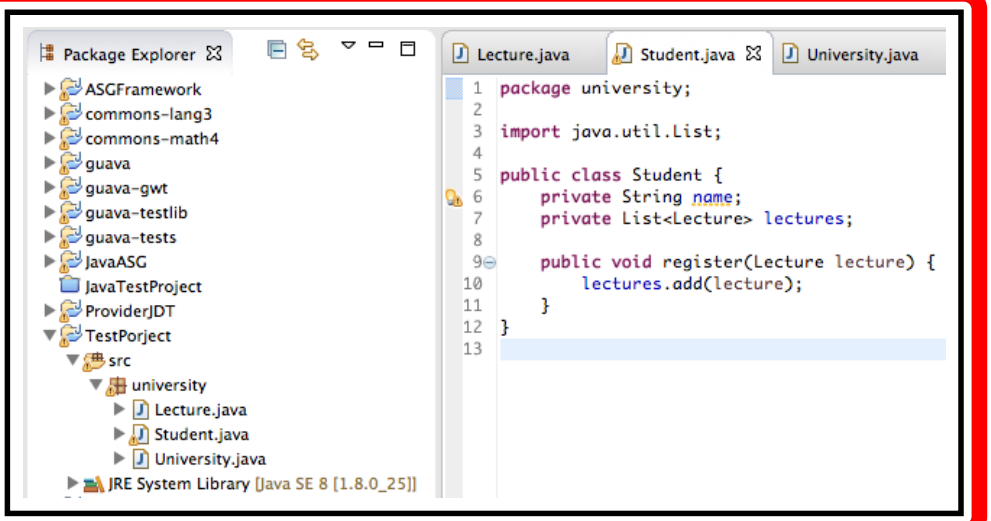

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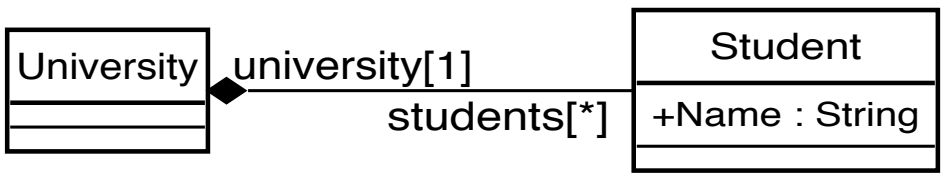


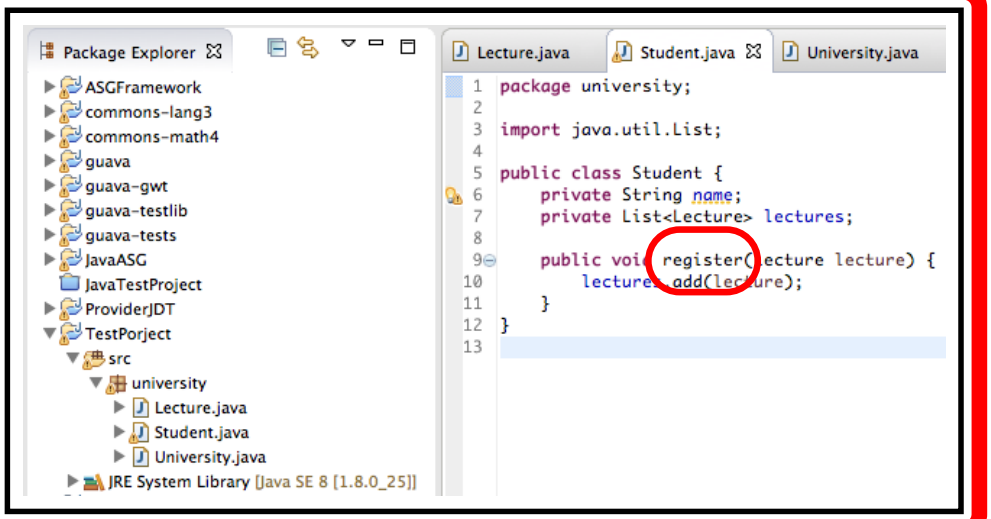

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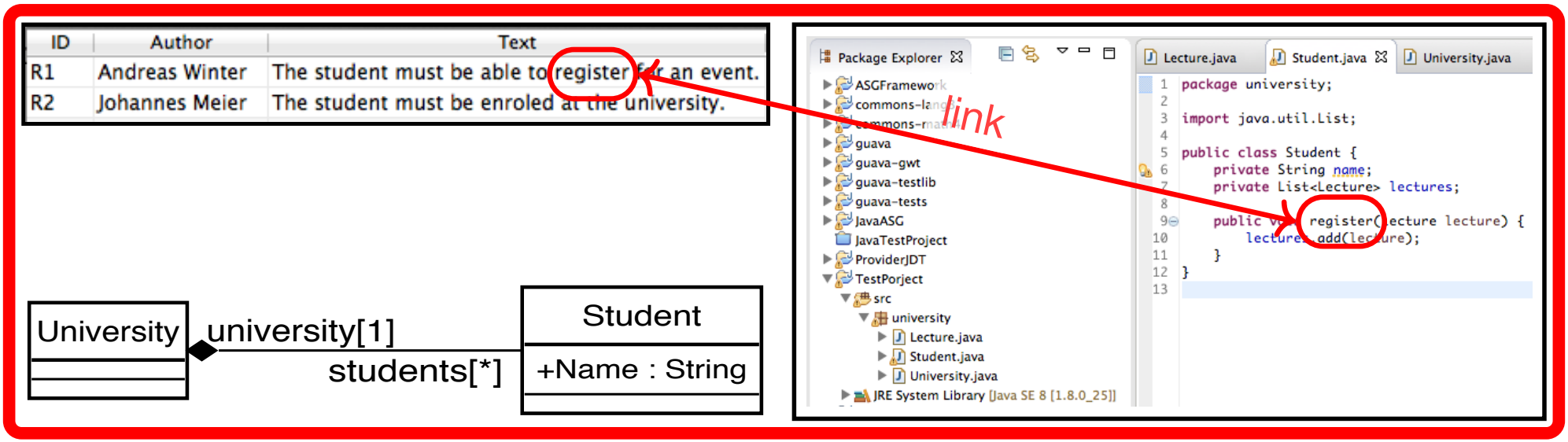

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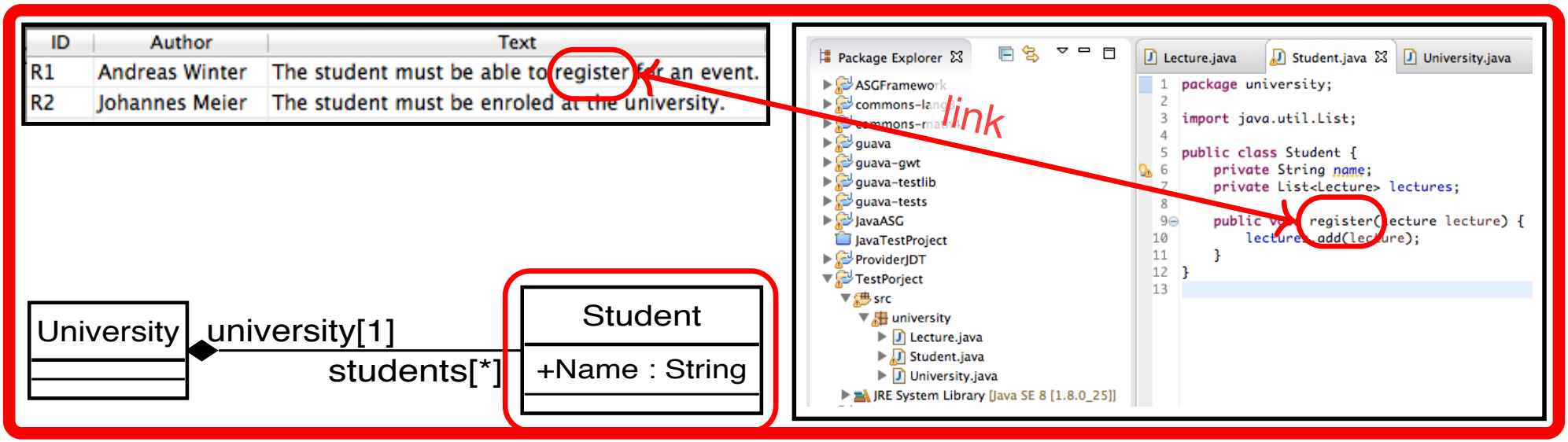

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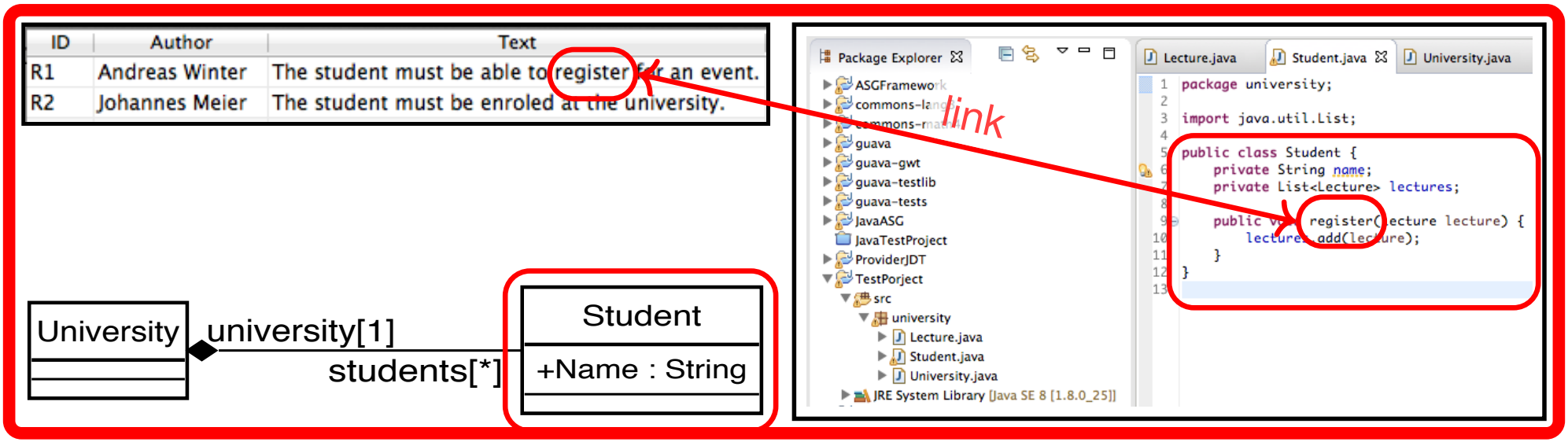

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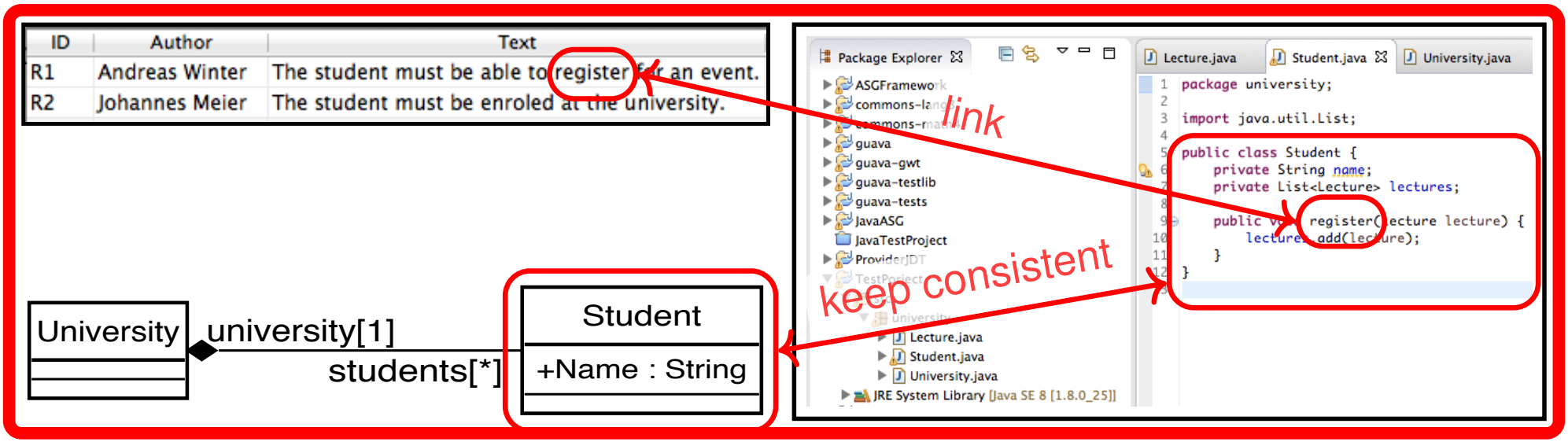

# Problem

There are further Software Development Projects:

- e.g. with formal Specifications, C++, Test Cases, Documentation, Project Management, Build Tools
- Traceability
- $\rightarrow$ further Consistency issues

General Problem:

- Artifacts are technically separated, but interrelated contentwise
- specific Consistency Rules have to be fulfilled automatically

## Goal

Ensure Consistency between Artifacts automatically!

- Artifact == Model + Metamodel (structural formalization [CNS12])
- $\rightarrow$ Model Integration

# Challenges

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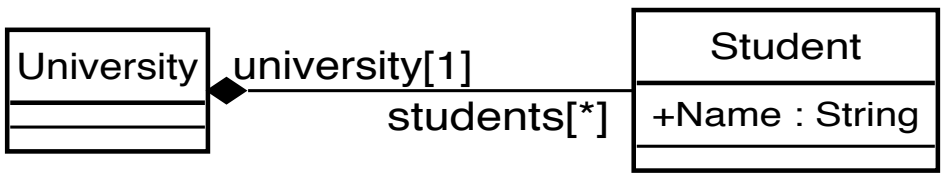


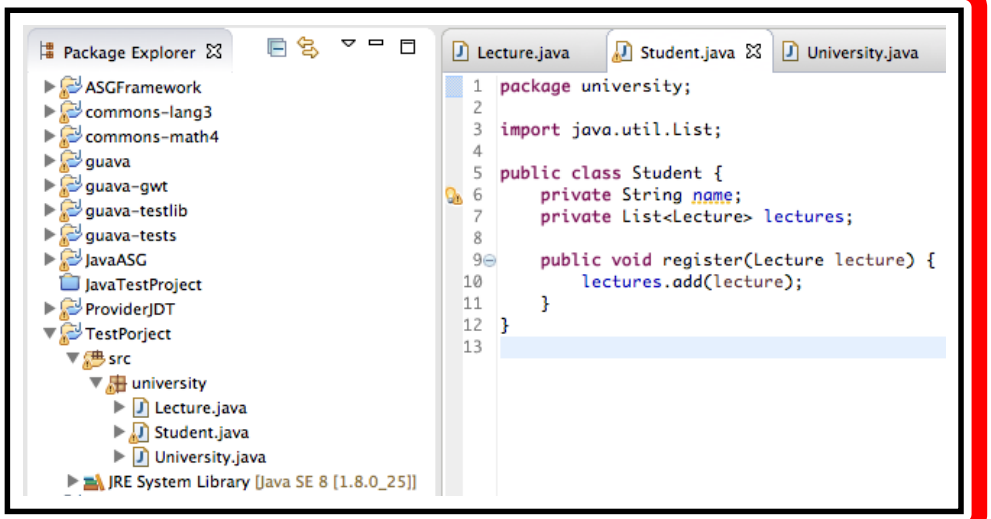

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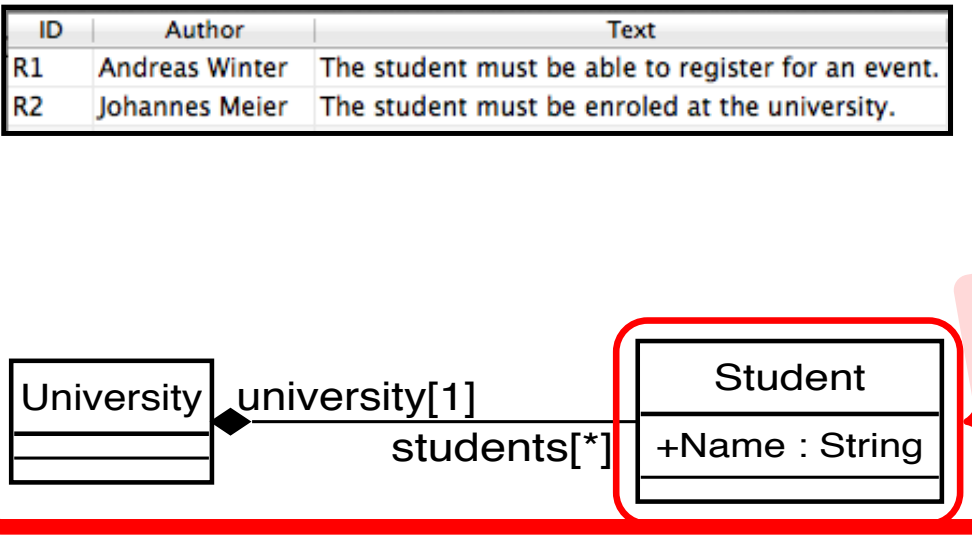


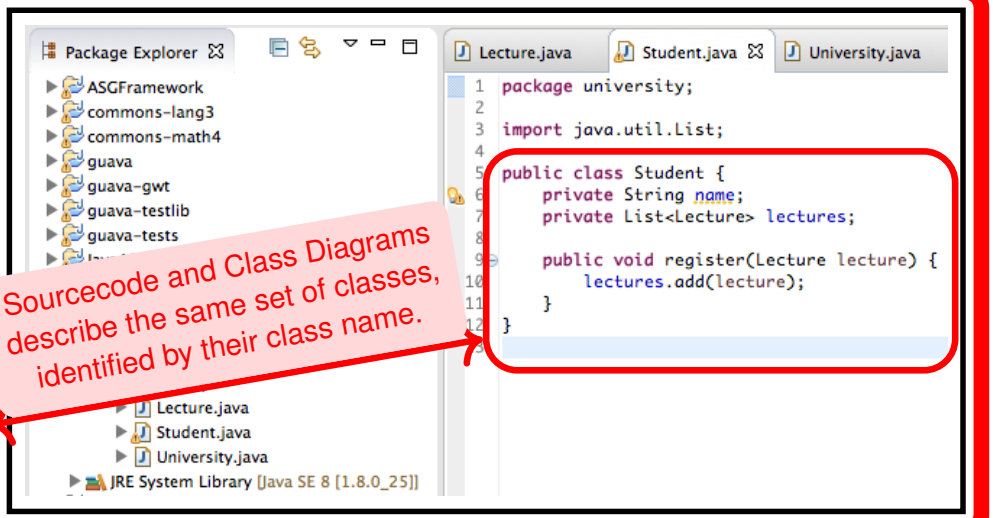


Sourcecode and Class Diagrams describe the same set of classes, identified by their class name.

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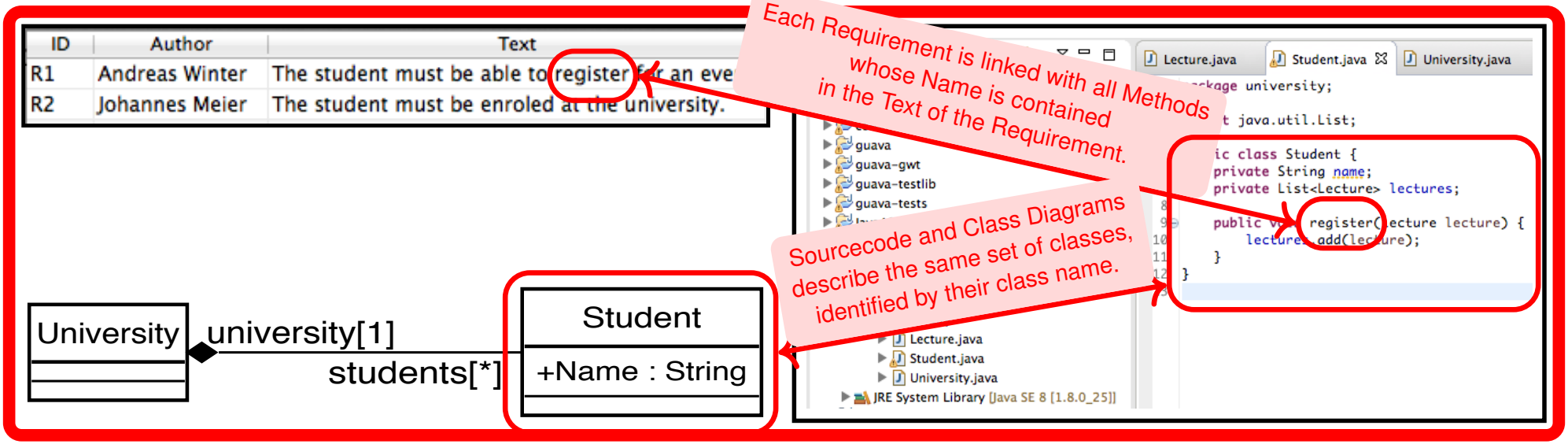

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- used as single Point of Truth
- Single Underlying Model [ASB09]
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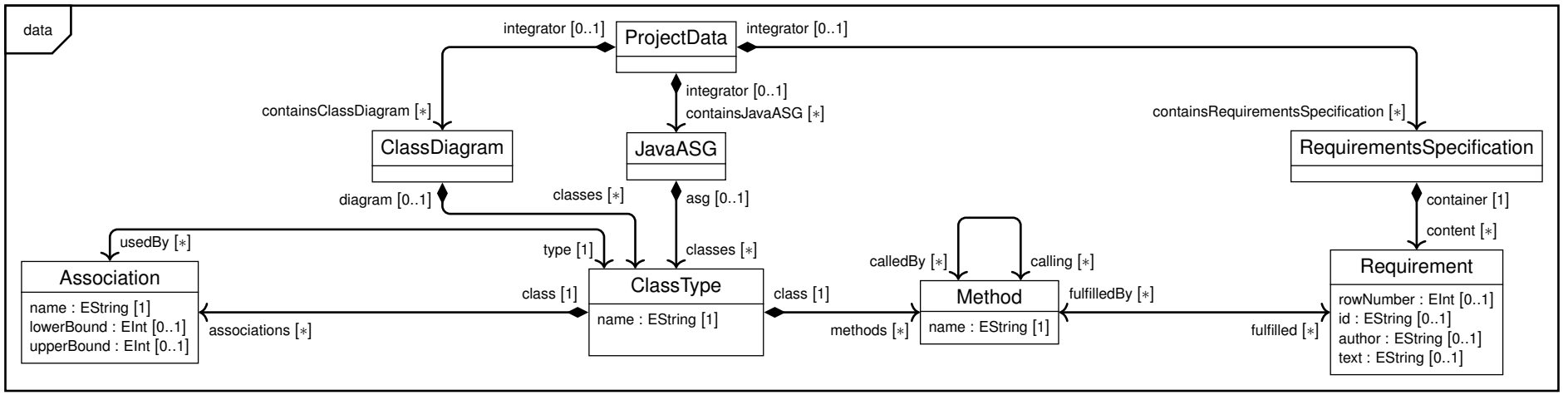


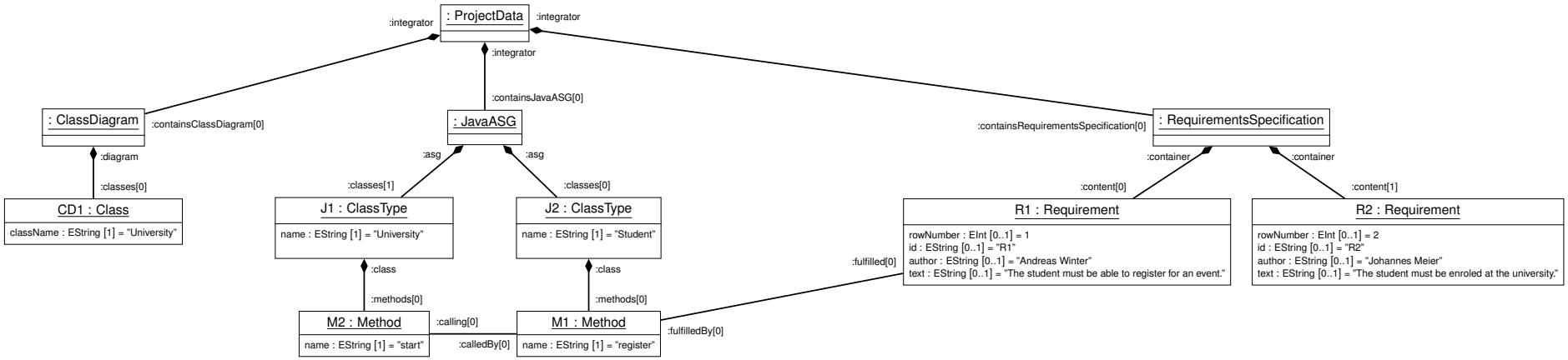

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- existing Models:
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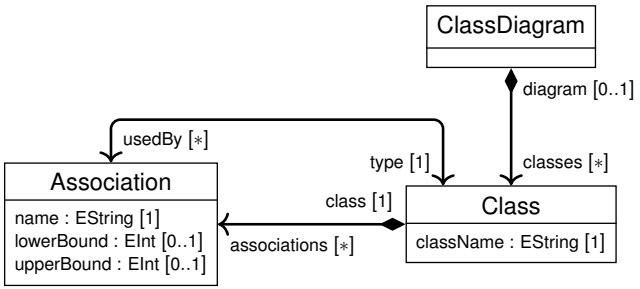


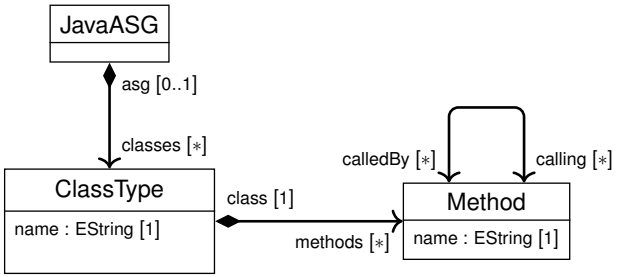


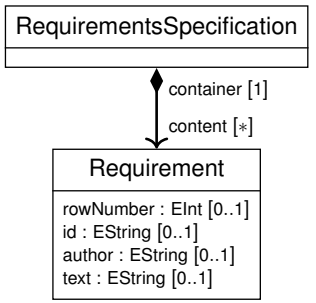


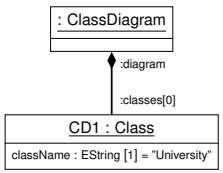


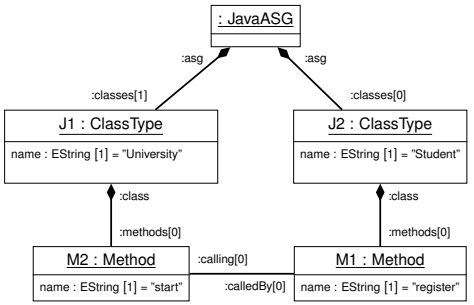


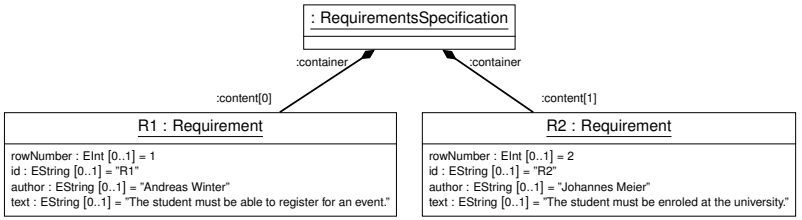

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# Related Work

| | synthetic | projectional | | |
|---|---|---|---|---|
| | | OSM | Vitruvius | GEMOC |
| 1. Formalize Consistency Rules | ✓ | ✓ | ✓ | ✓ |
| 2. Create explicit SUM(M) | ✗ | ✓ | ✗ | ✗ |
| 3a. Reuse initial Models | ✓ | ✗ | ✓ | ✓ |
| 3b. Fix initial Inconsistencies | ✓ | – | ✗ | ? |
| 3c. Consistent initial Models | ✓ | – | ✓ | ✓ |
| 4. Ensure Model Consistency | ✓ | ✓ | ✓ | ✓ |

- ISO Standard 42010:2011 [IEE11]: synthetic vs. projectional
- synthetic: TGGs [SK08], QVT-R [RJV09], explicit correspondences [EEC+14]
- OSM: Single Underlying (Meta)Model (SUM(M)) [ASB09]
- Vitruvius [KBL13, BHK+14]
- GEMOC Approach [LDC18]

# Metamodel Integration

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**Activities**

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1. Configuration of Operators

SUMM

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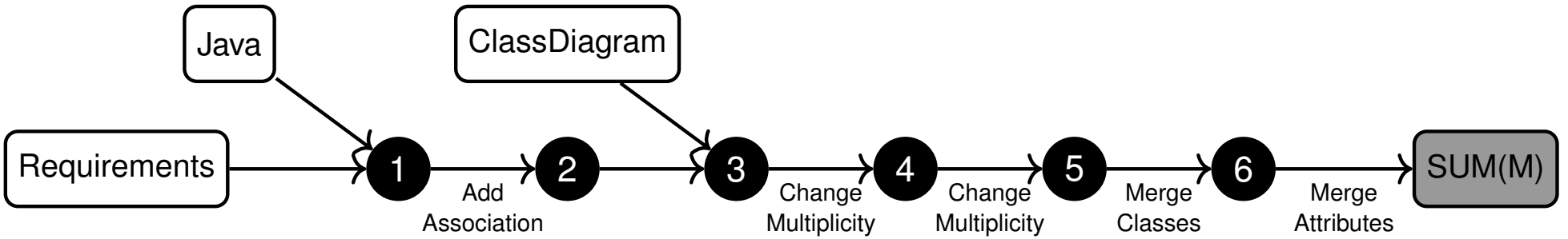

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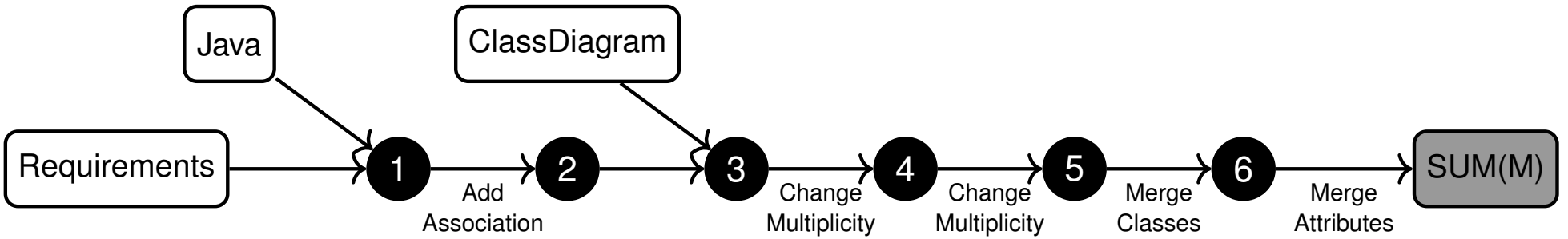

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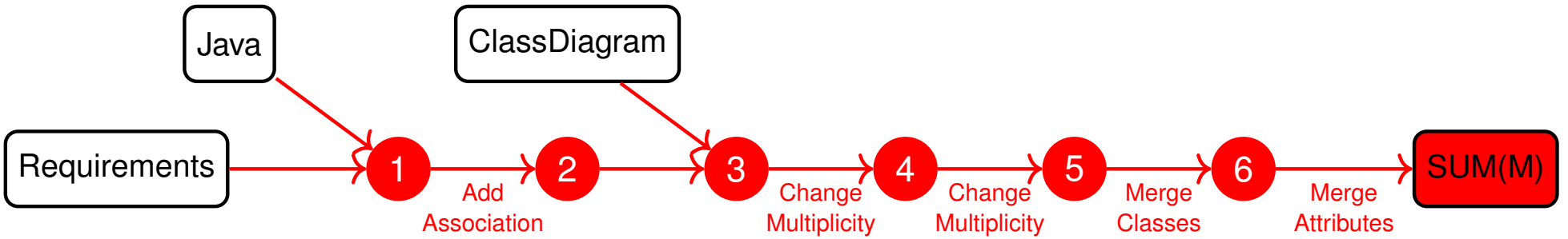

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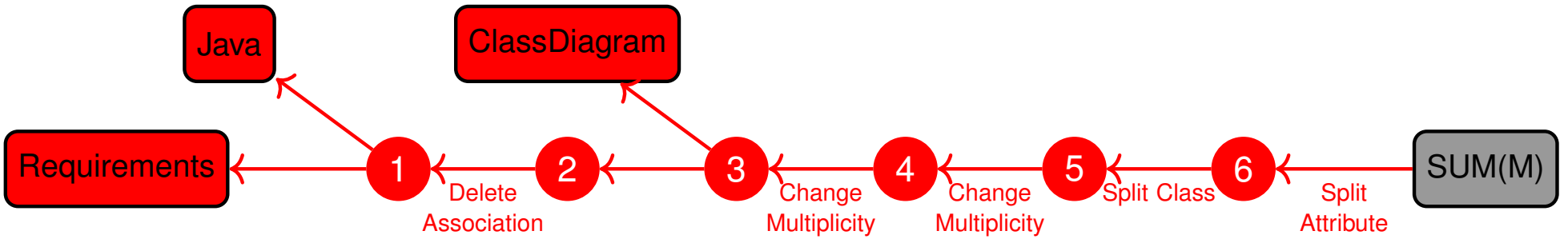

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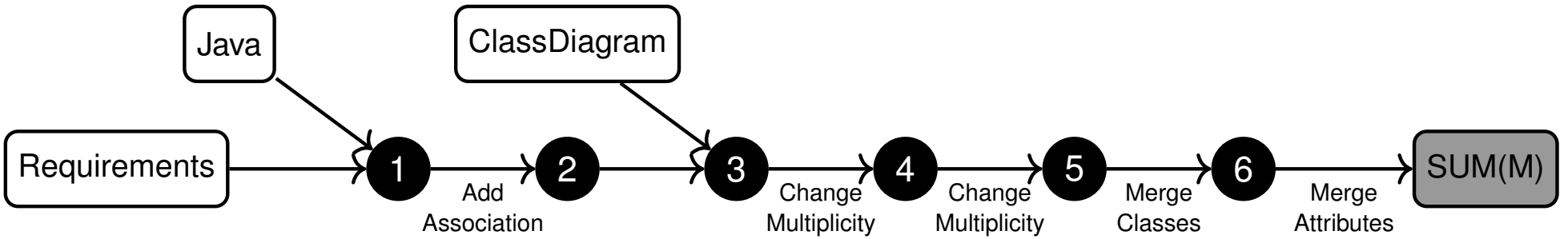

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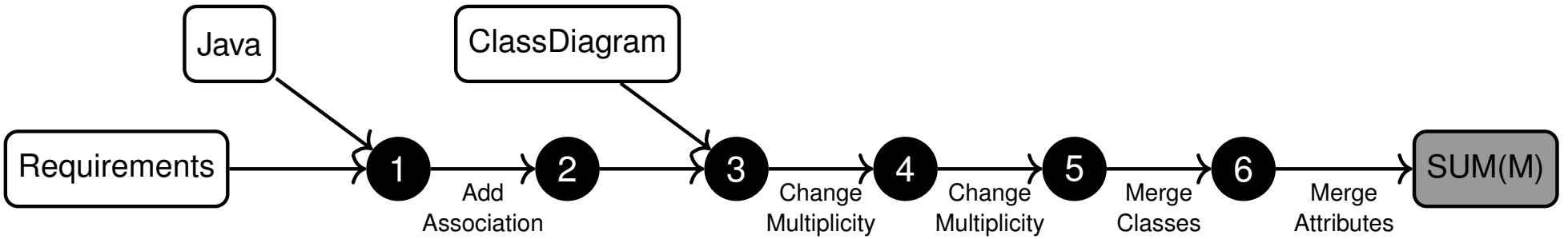
1x Methodologist



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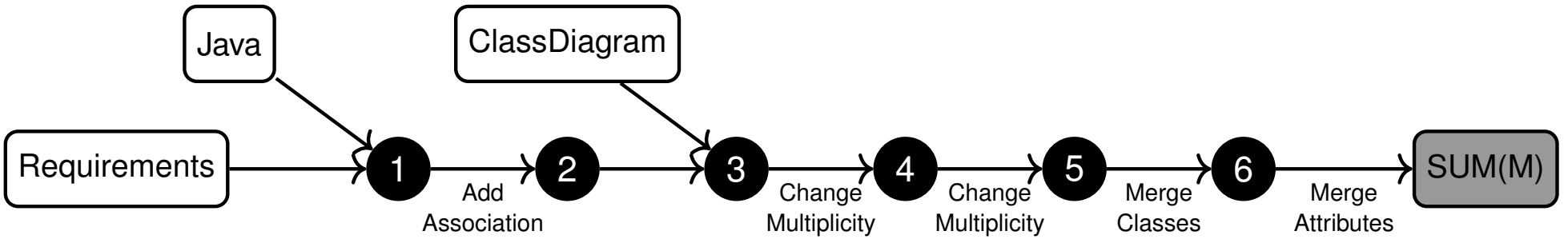
*n x* User



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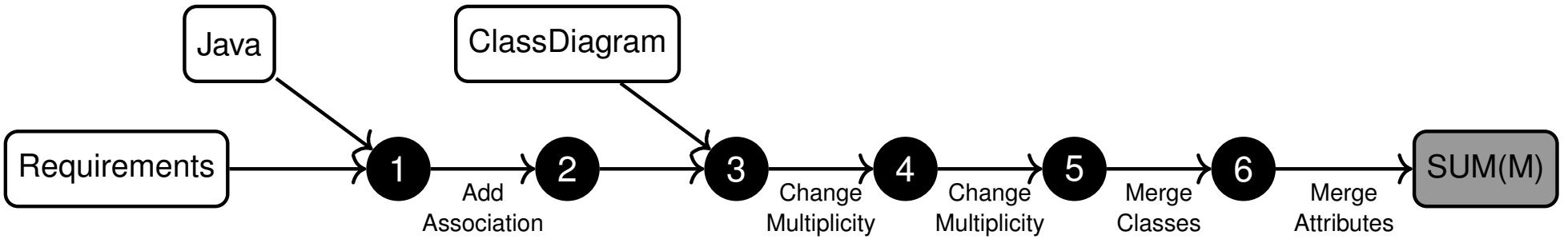

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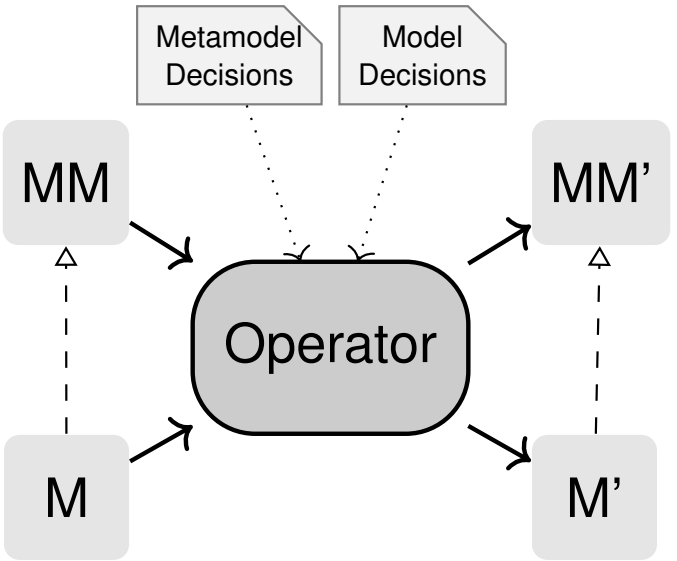


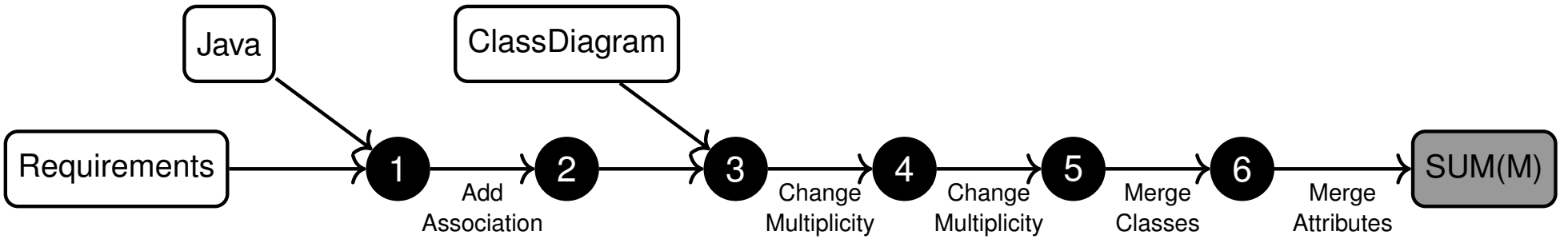

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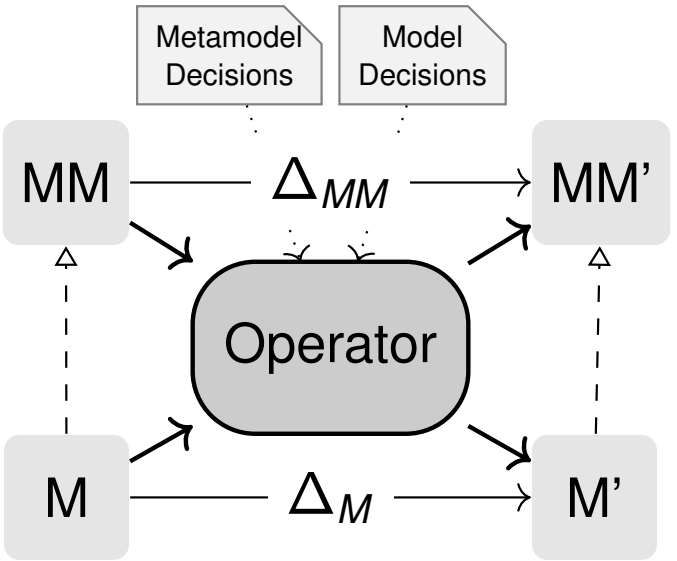


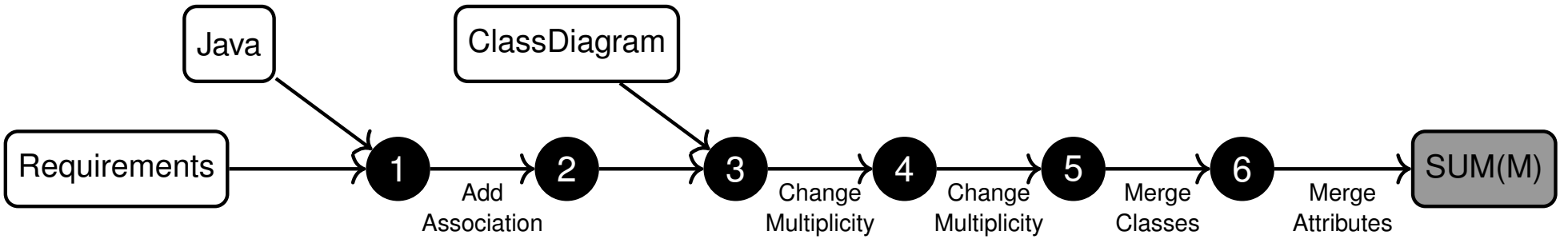

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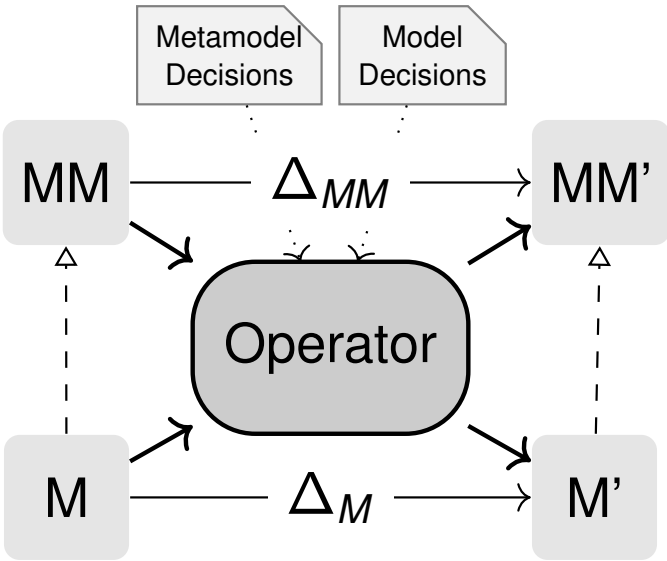
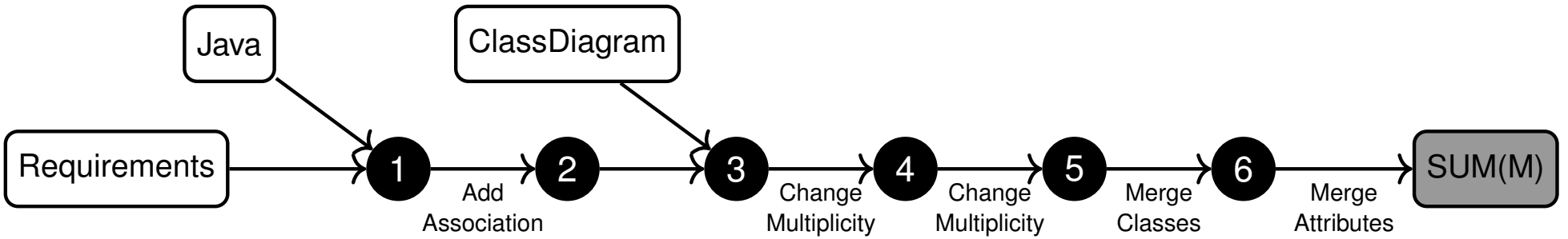



Chechik, Nejati, Sabetzadeh:
**A Relationship-Based Approach to Model Integration** (2012)

→ merge, composition, weaving

Herrmannsdoerfer et al.:
**An Extensive Catalog of Operators for the Coupled Evolution of Metamodels and Models** (2011)

→ extended Coupled Operators



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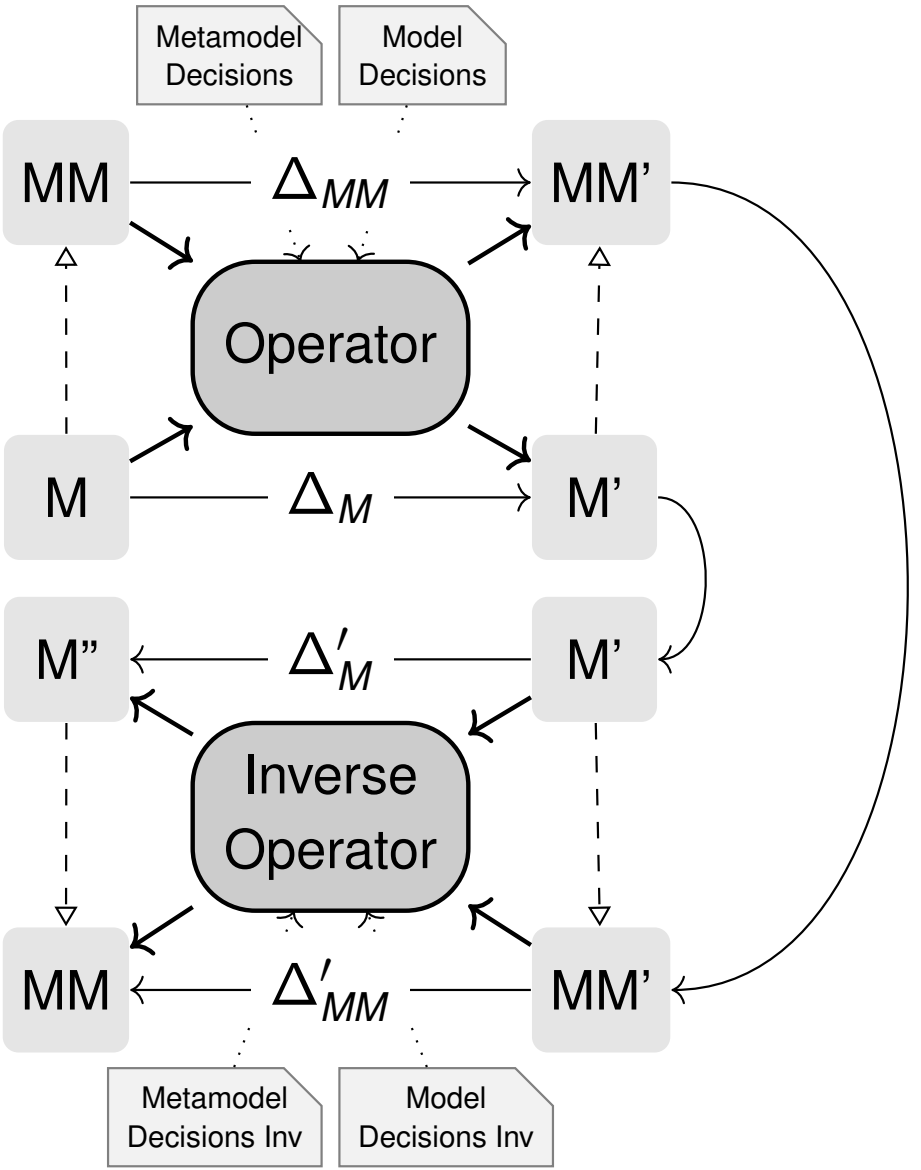

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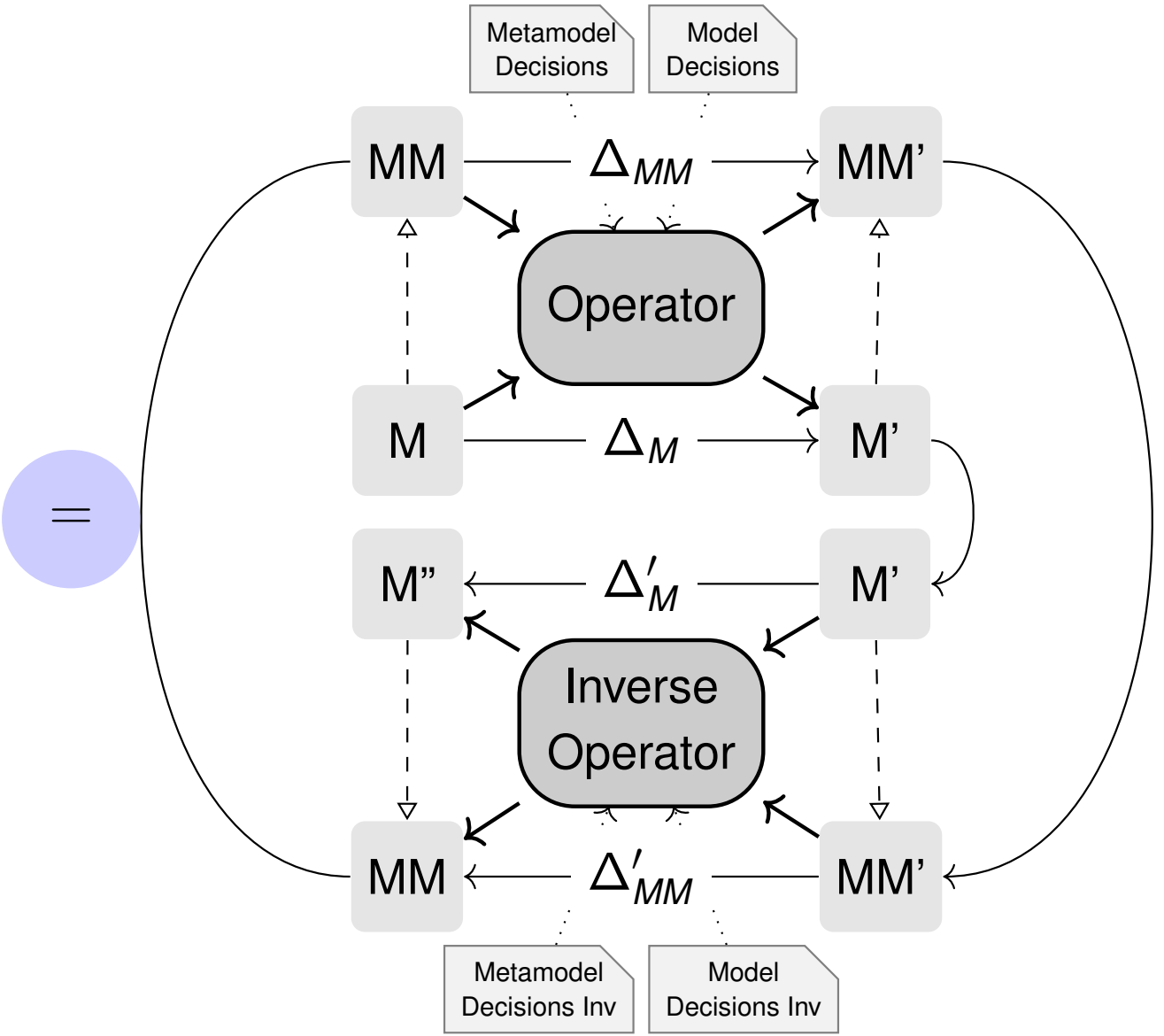

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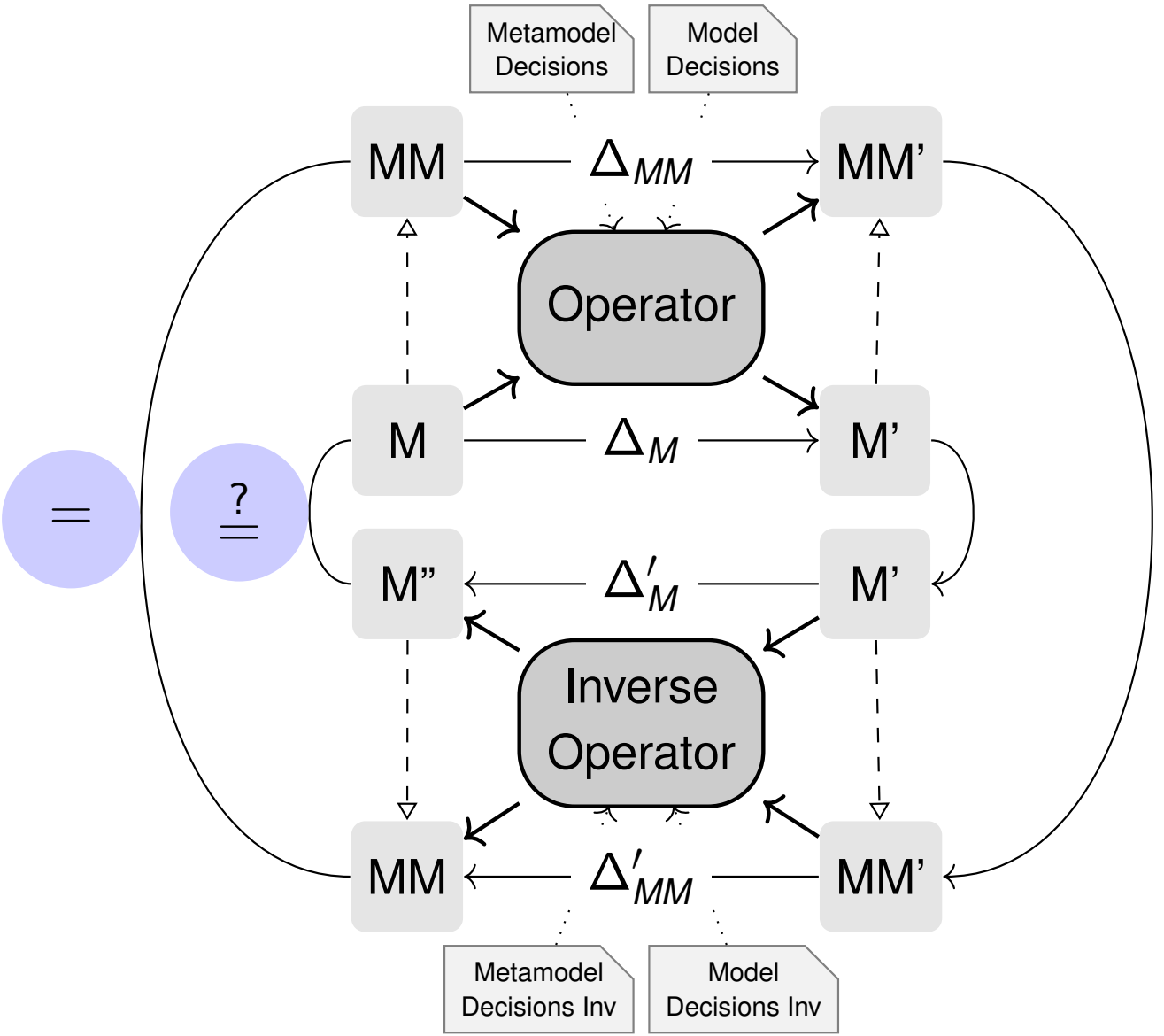

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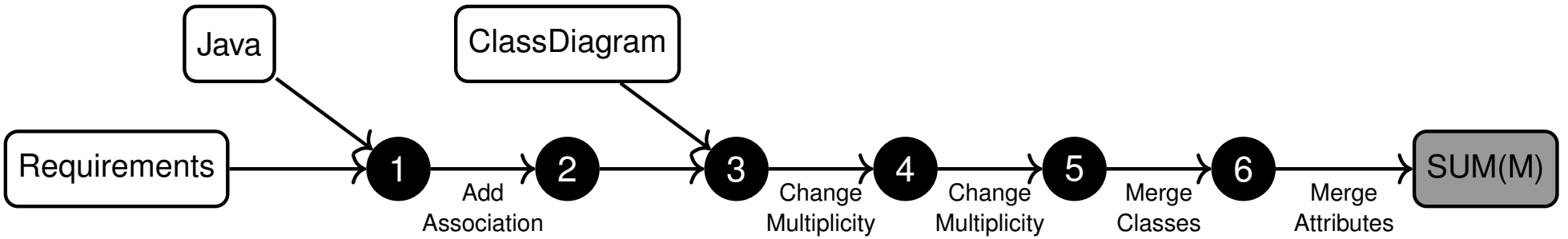

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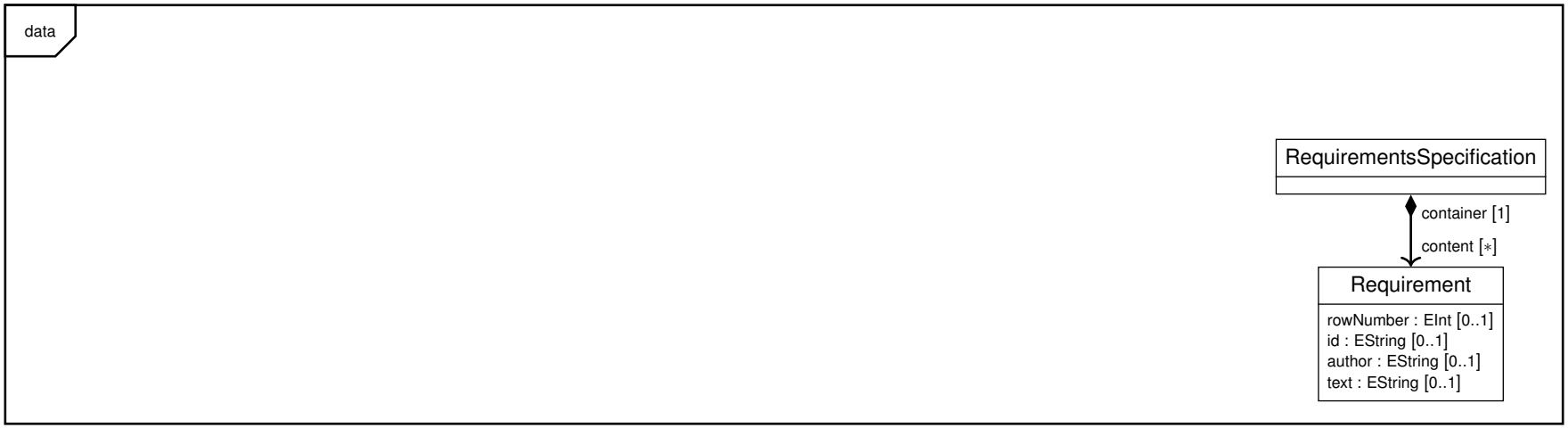


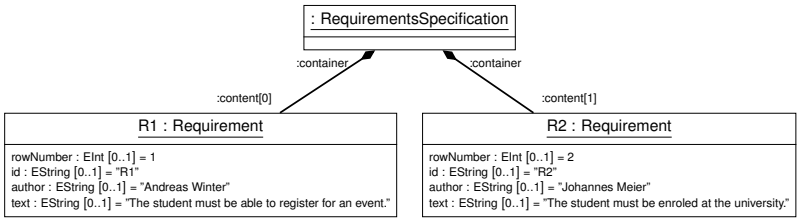


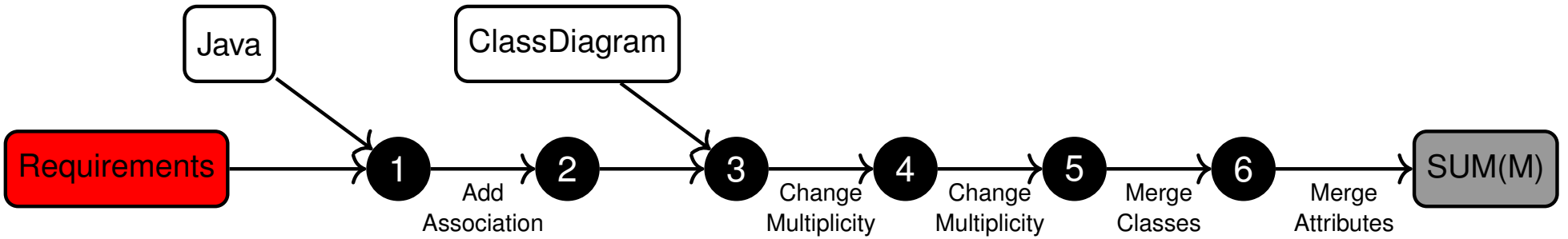

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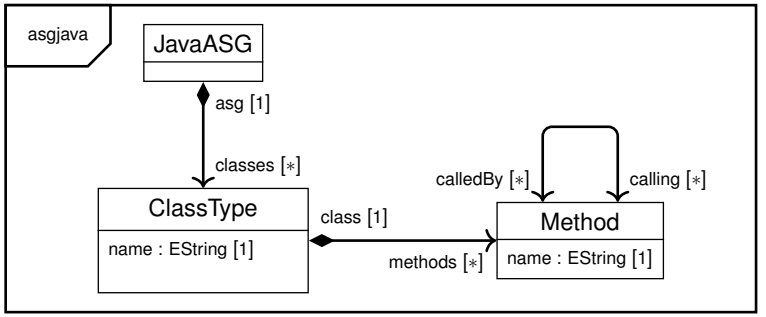


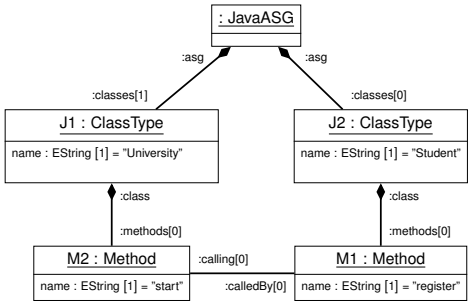


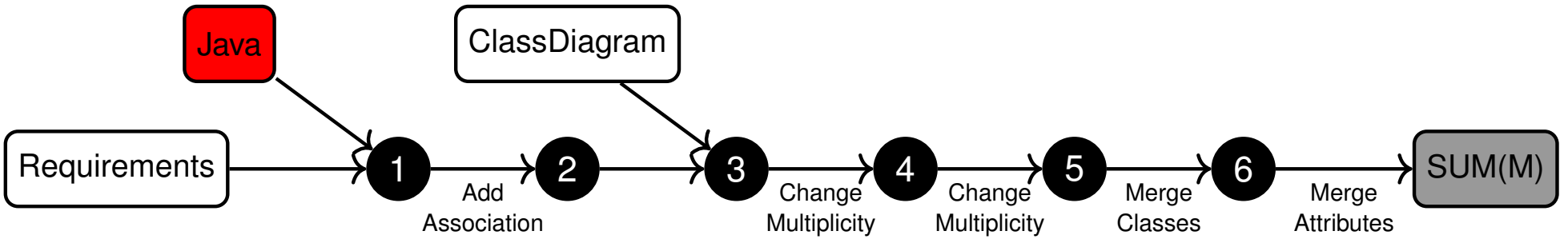

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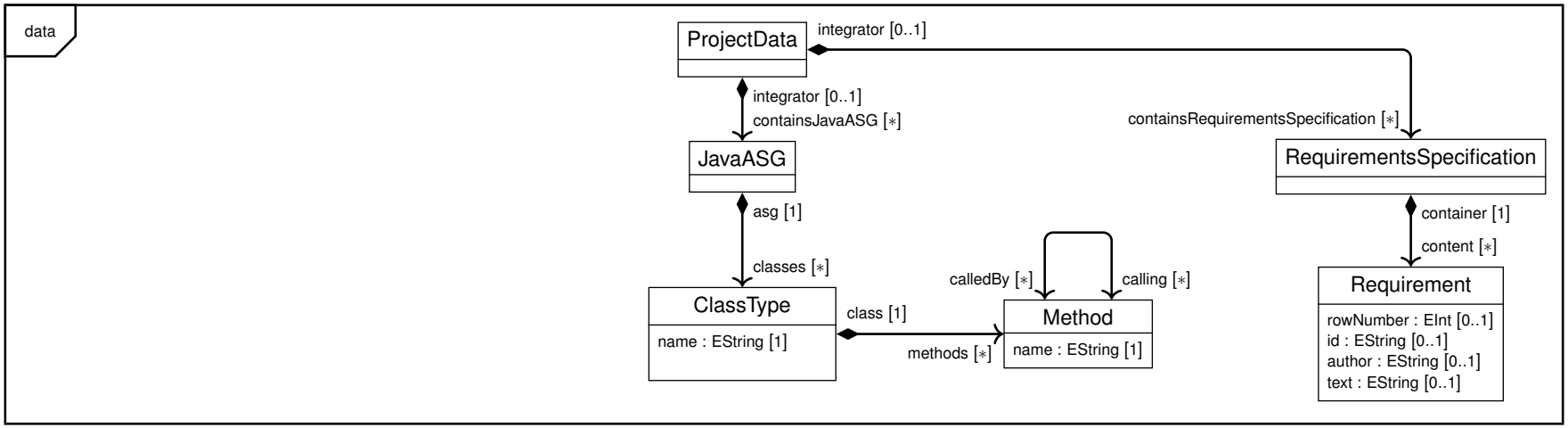


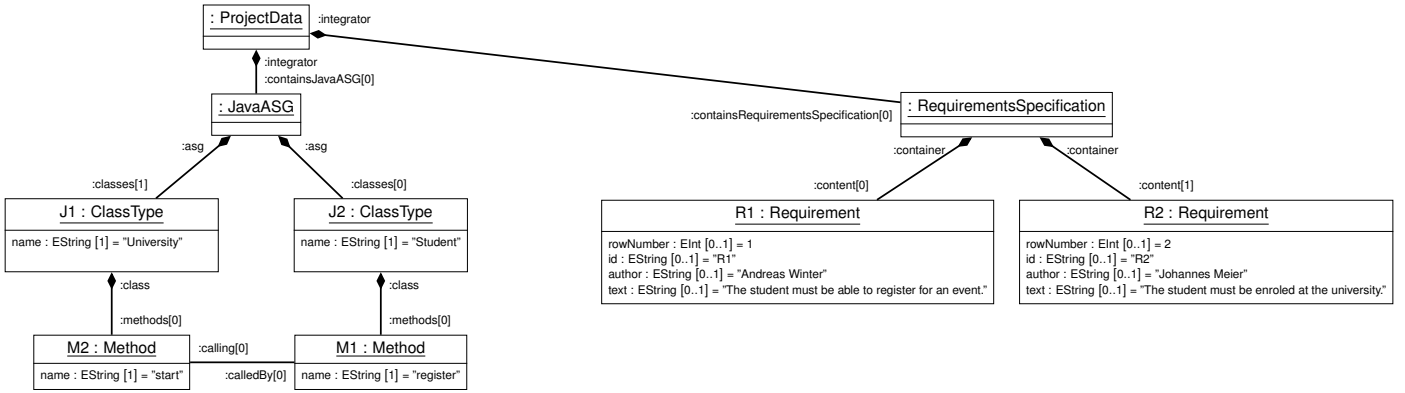


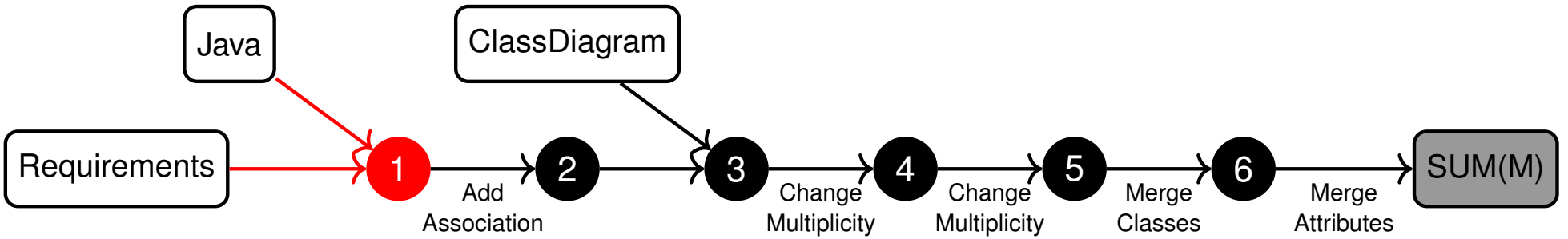

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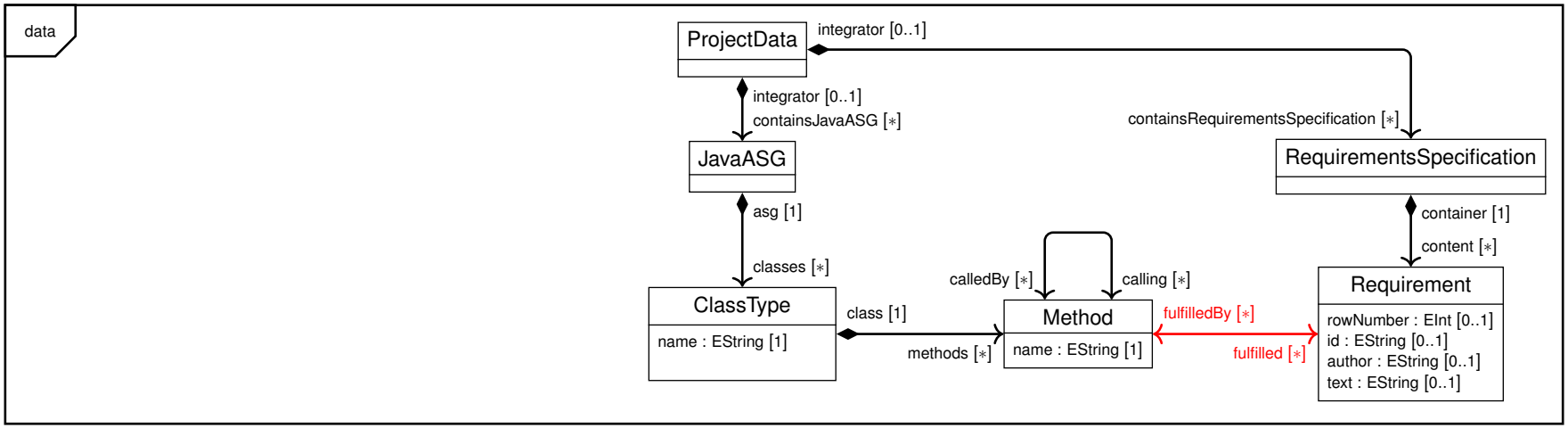


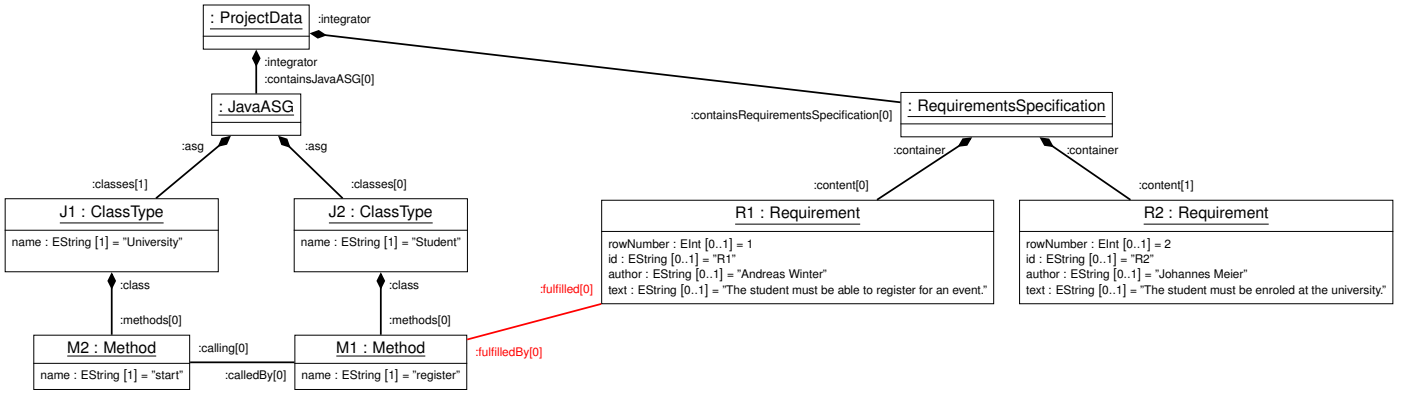


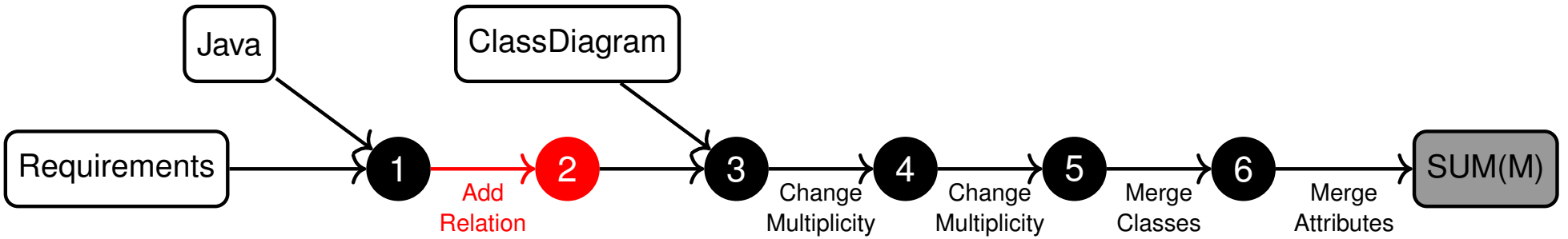

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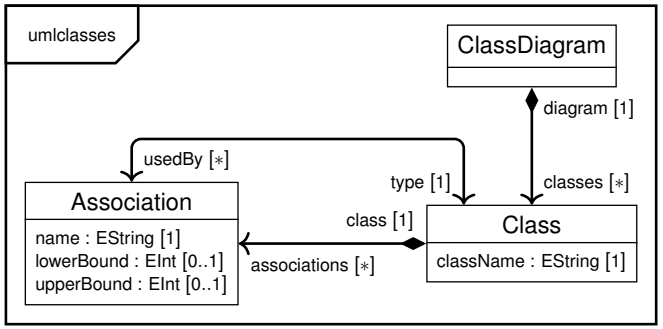


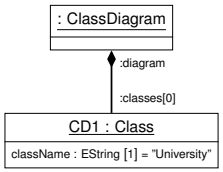


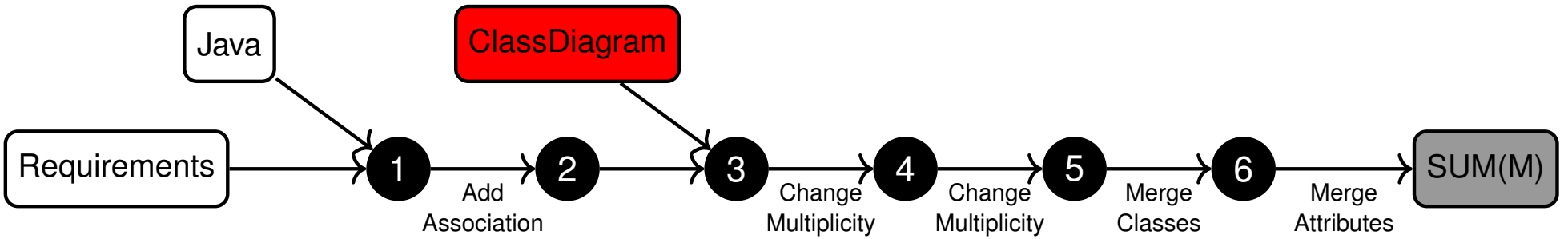

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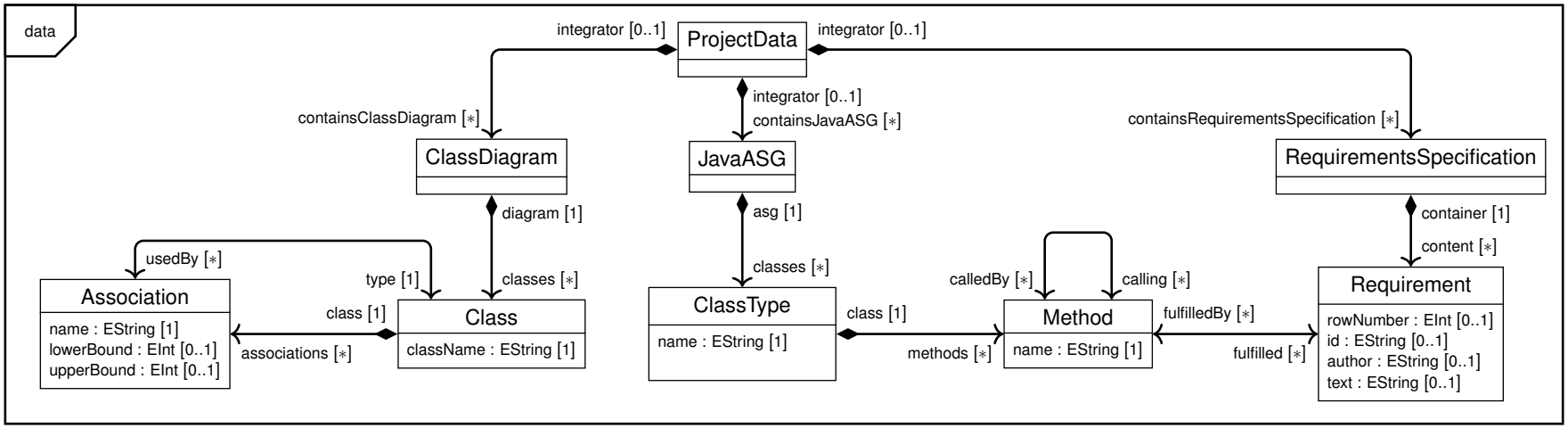


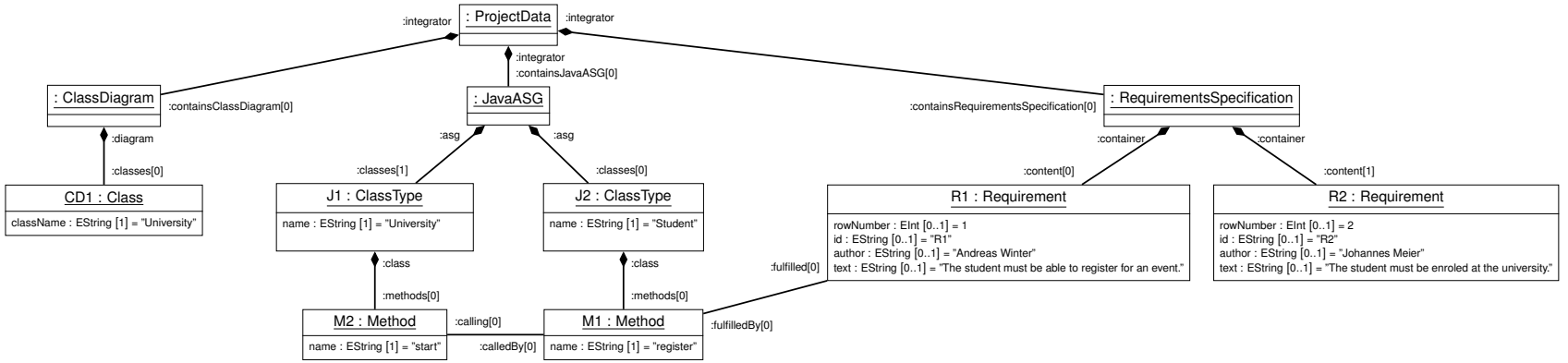


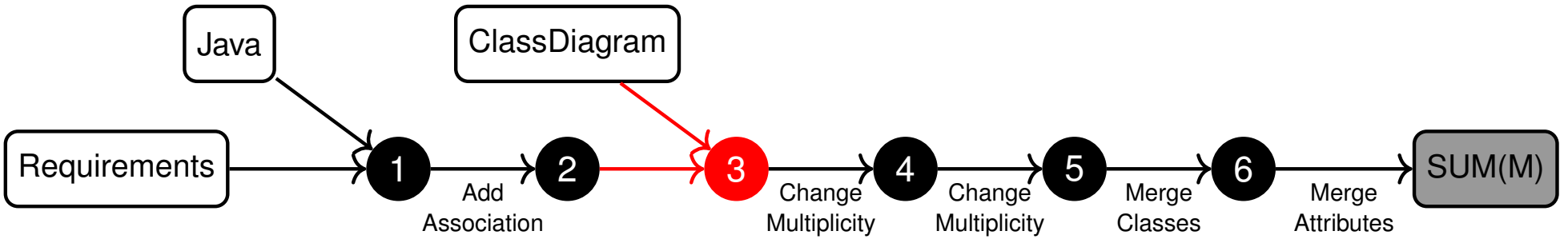

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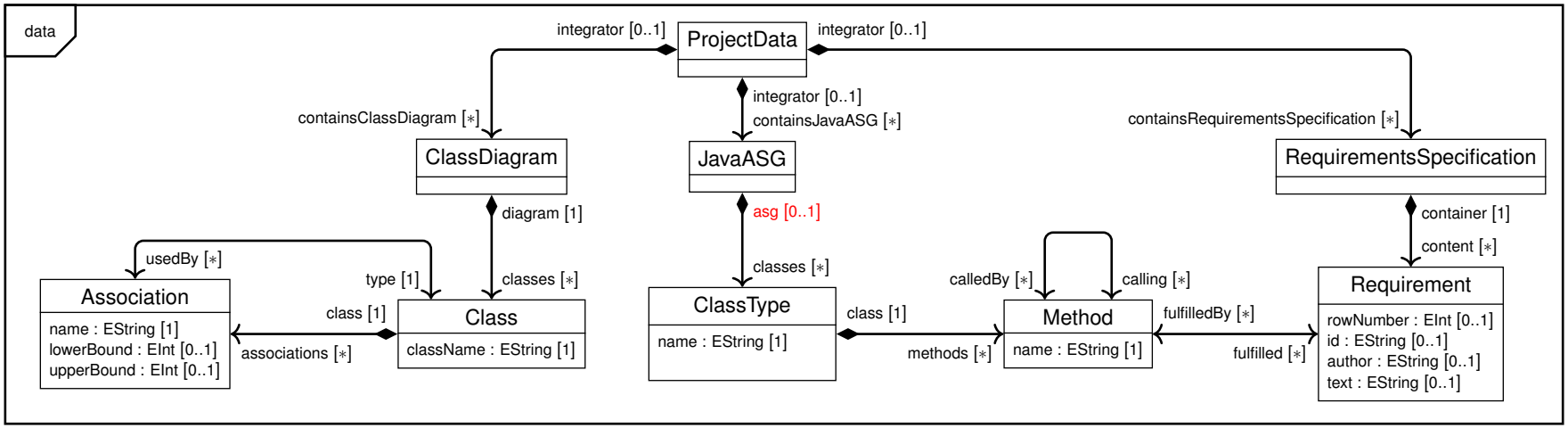


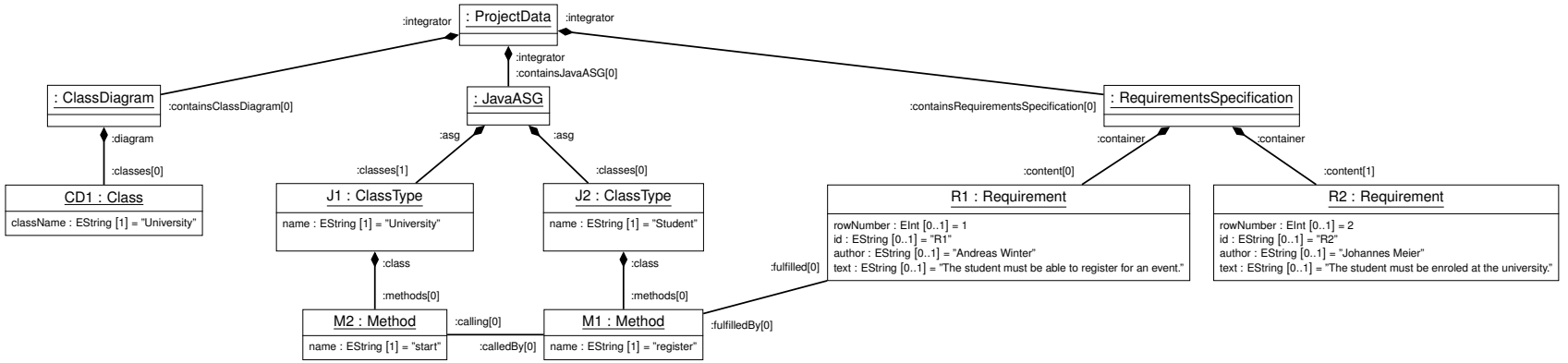


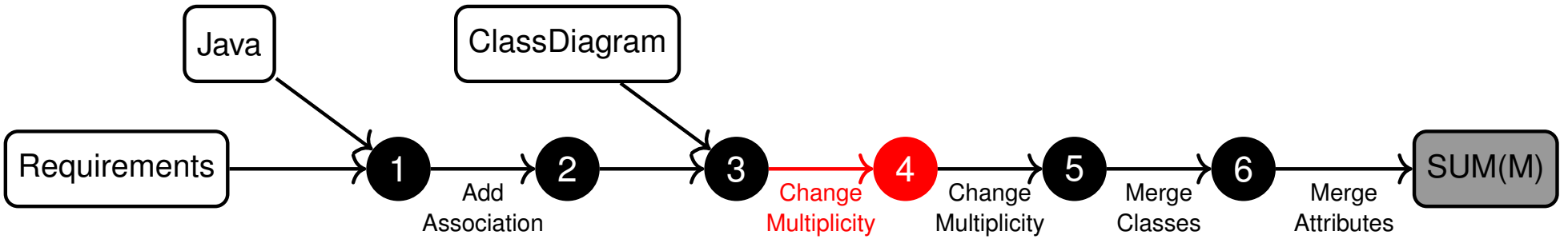

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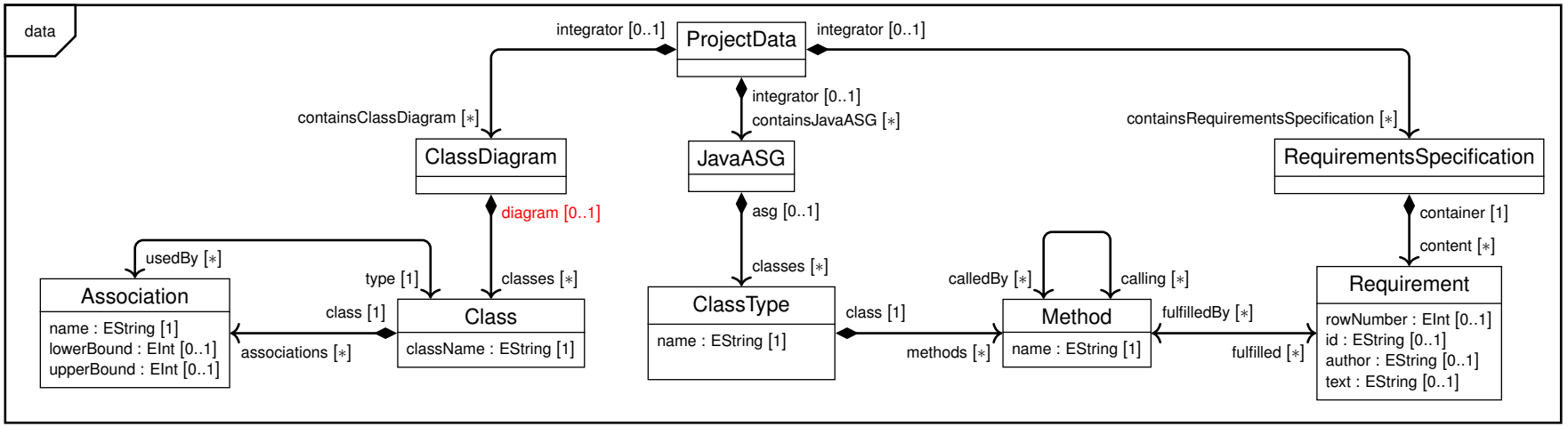


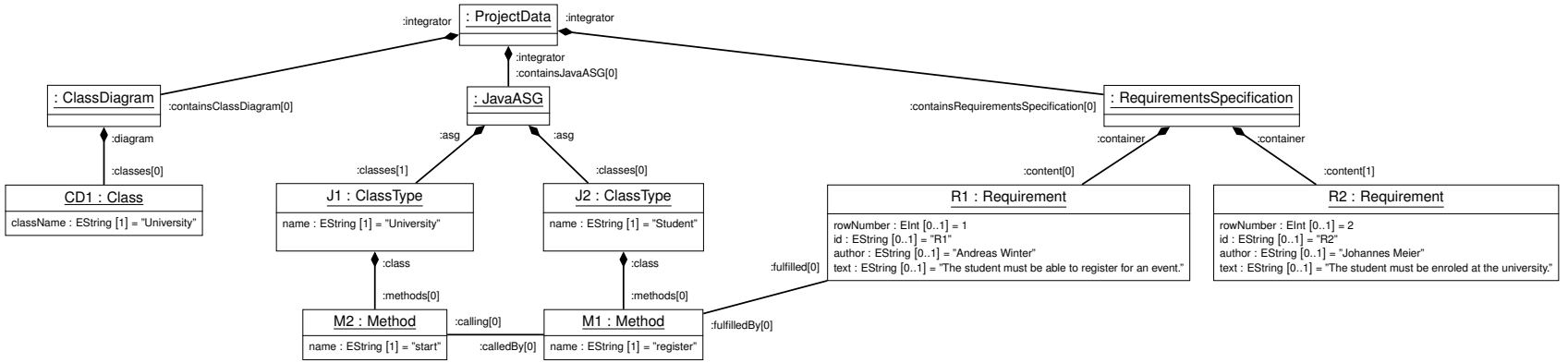


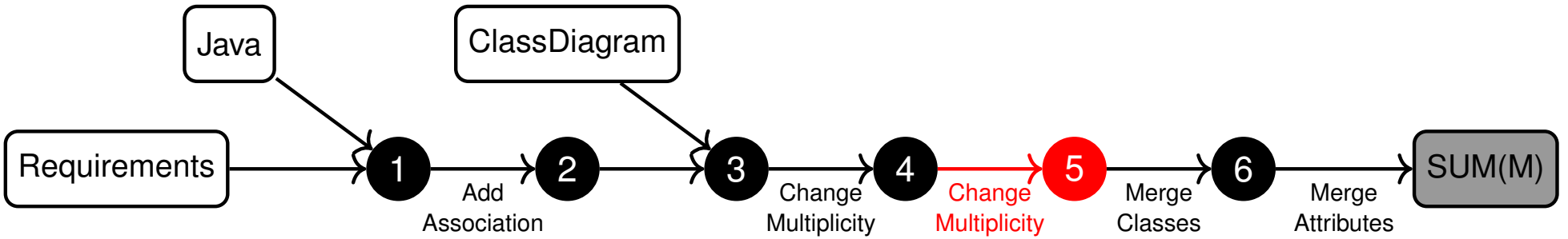

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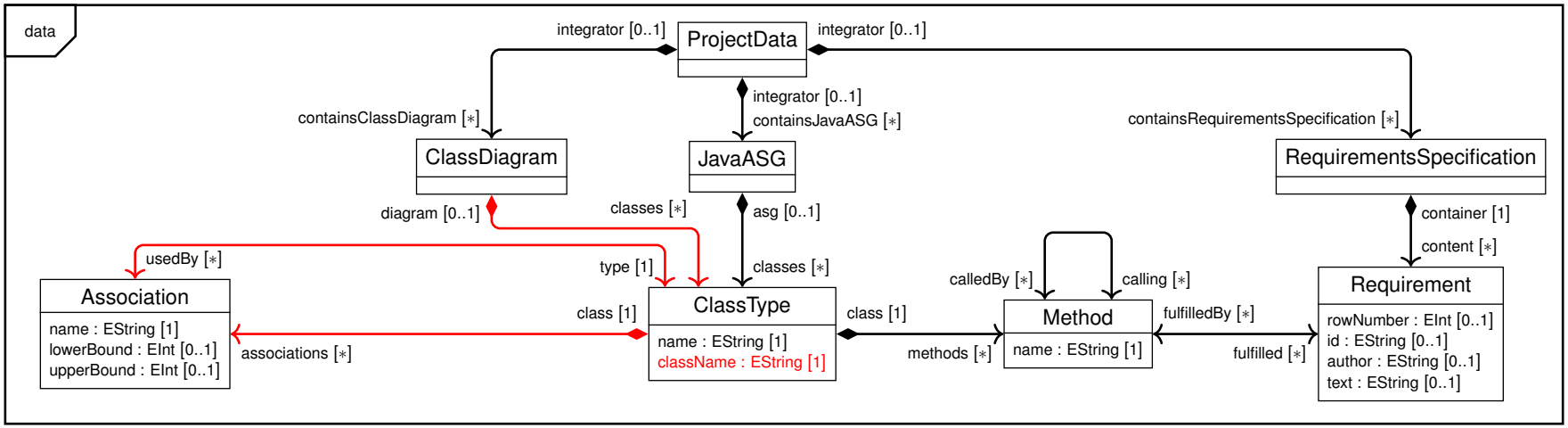


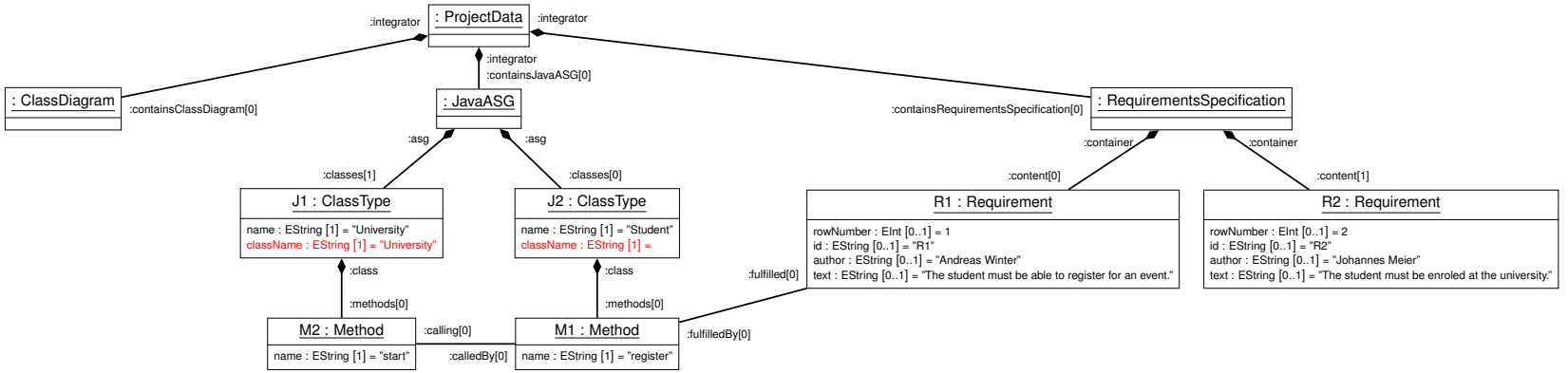


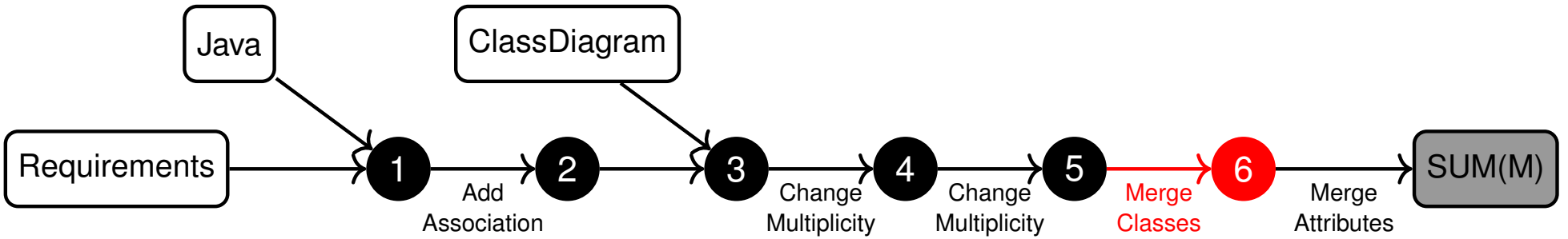

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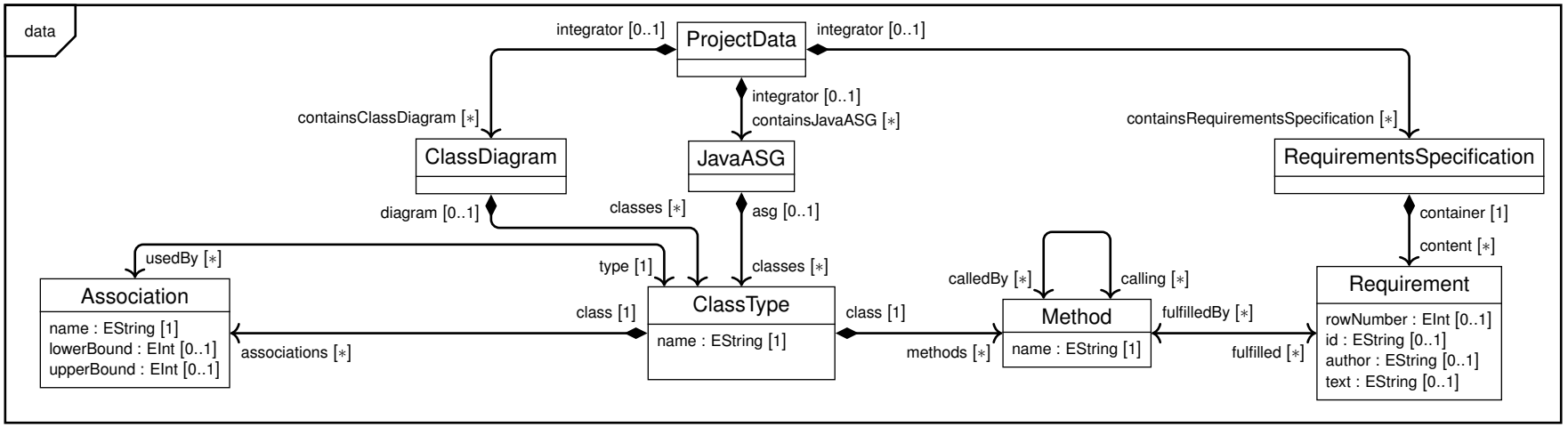


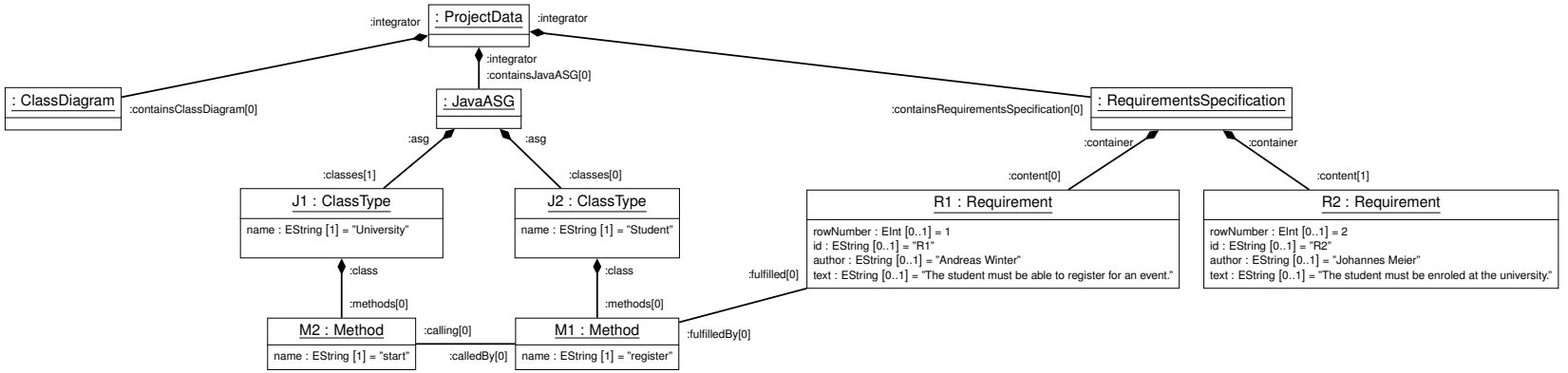


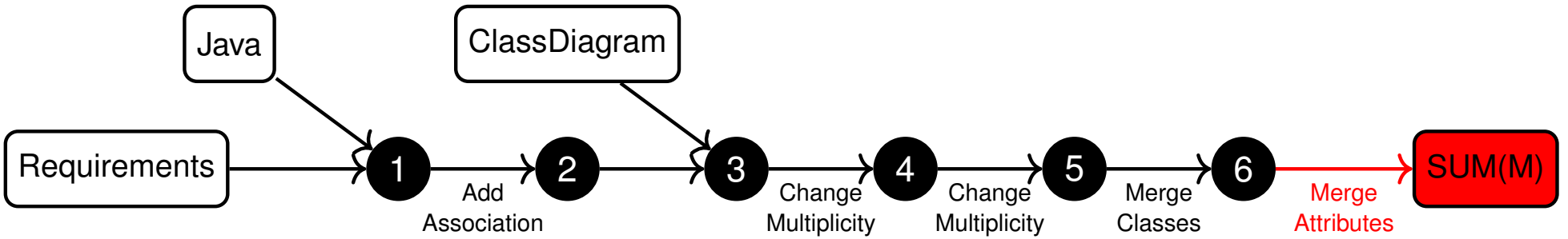

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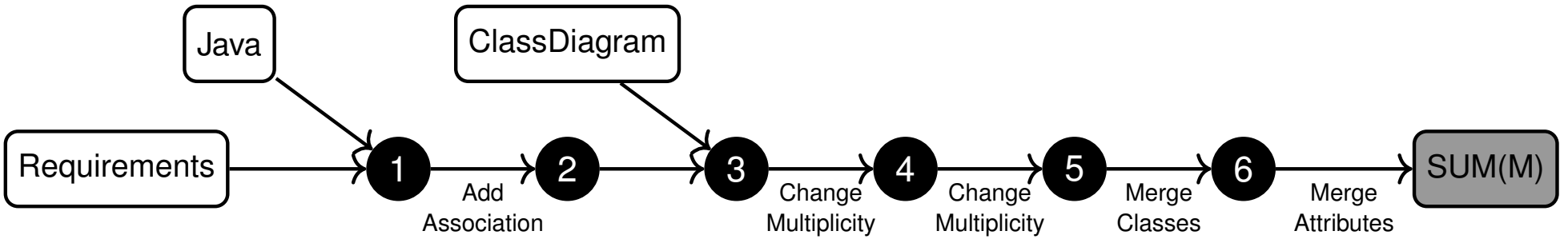

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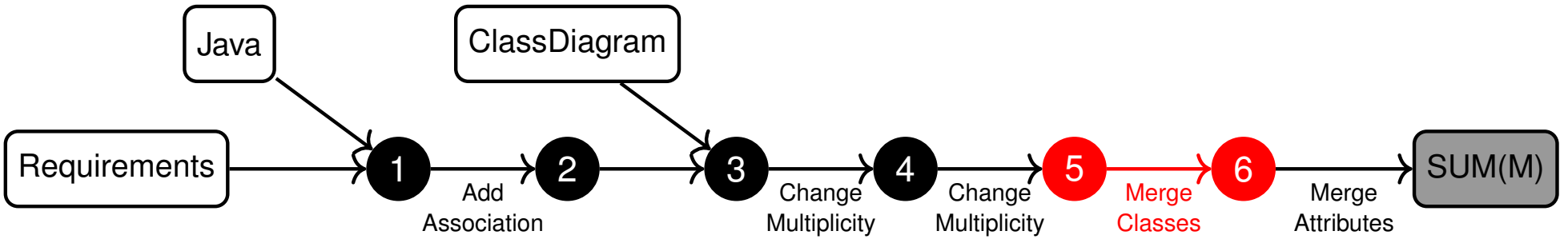

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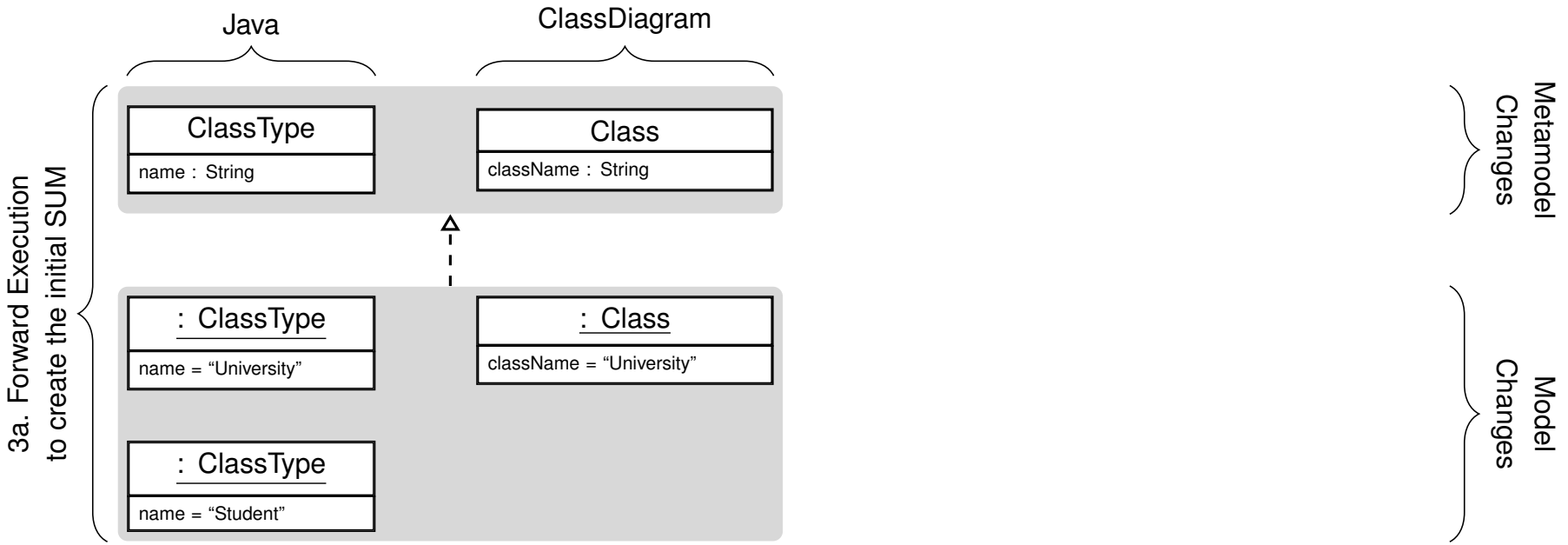


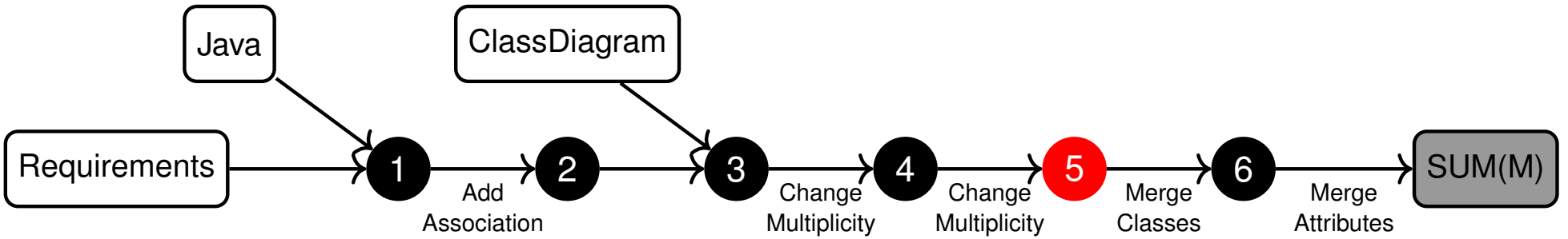

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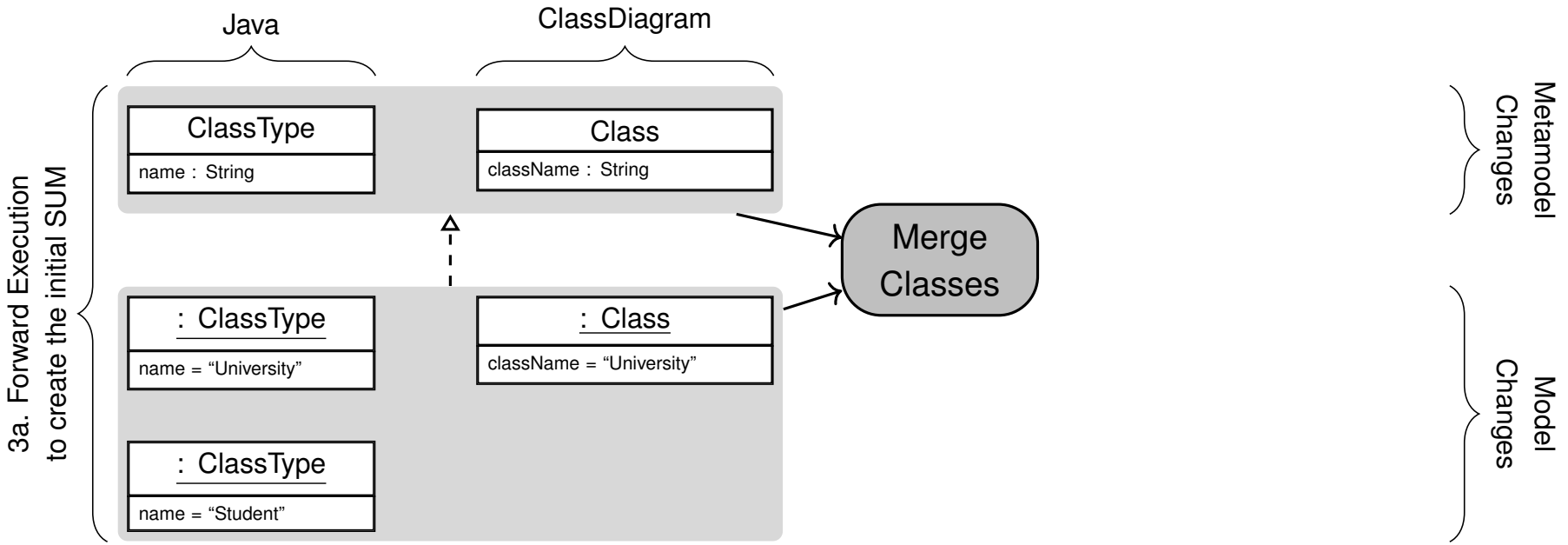


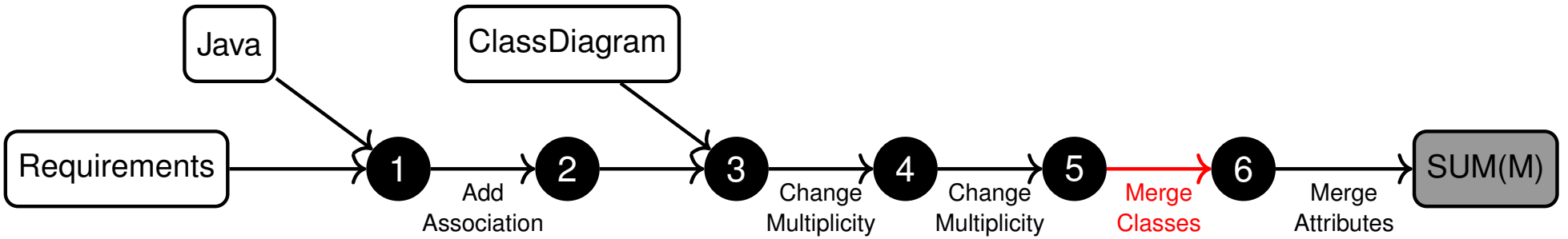

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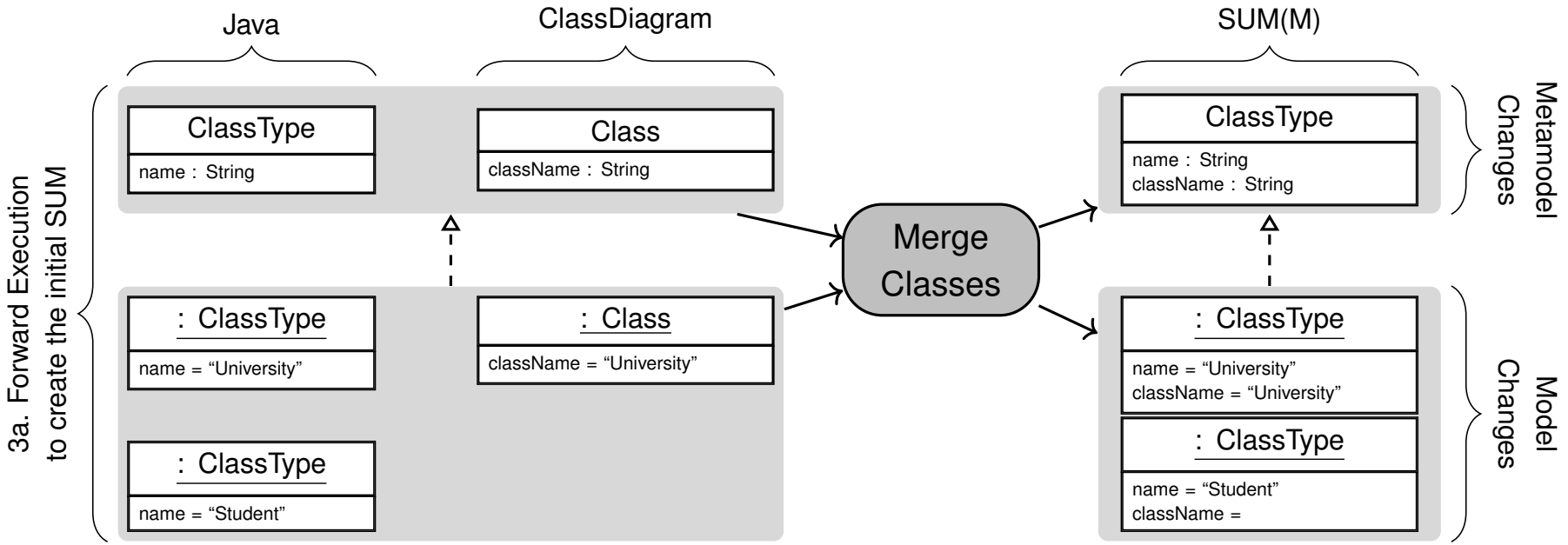


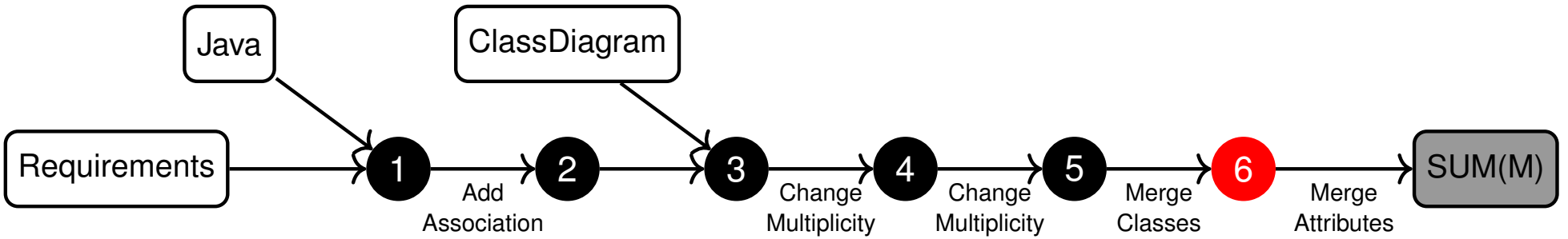

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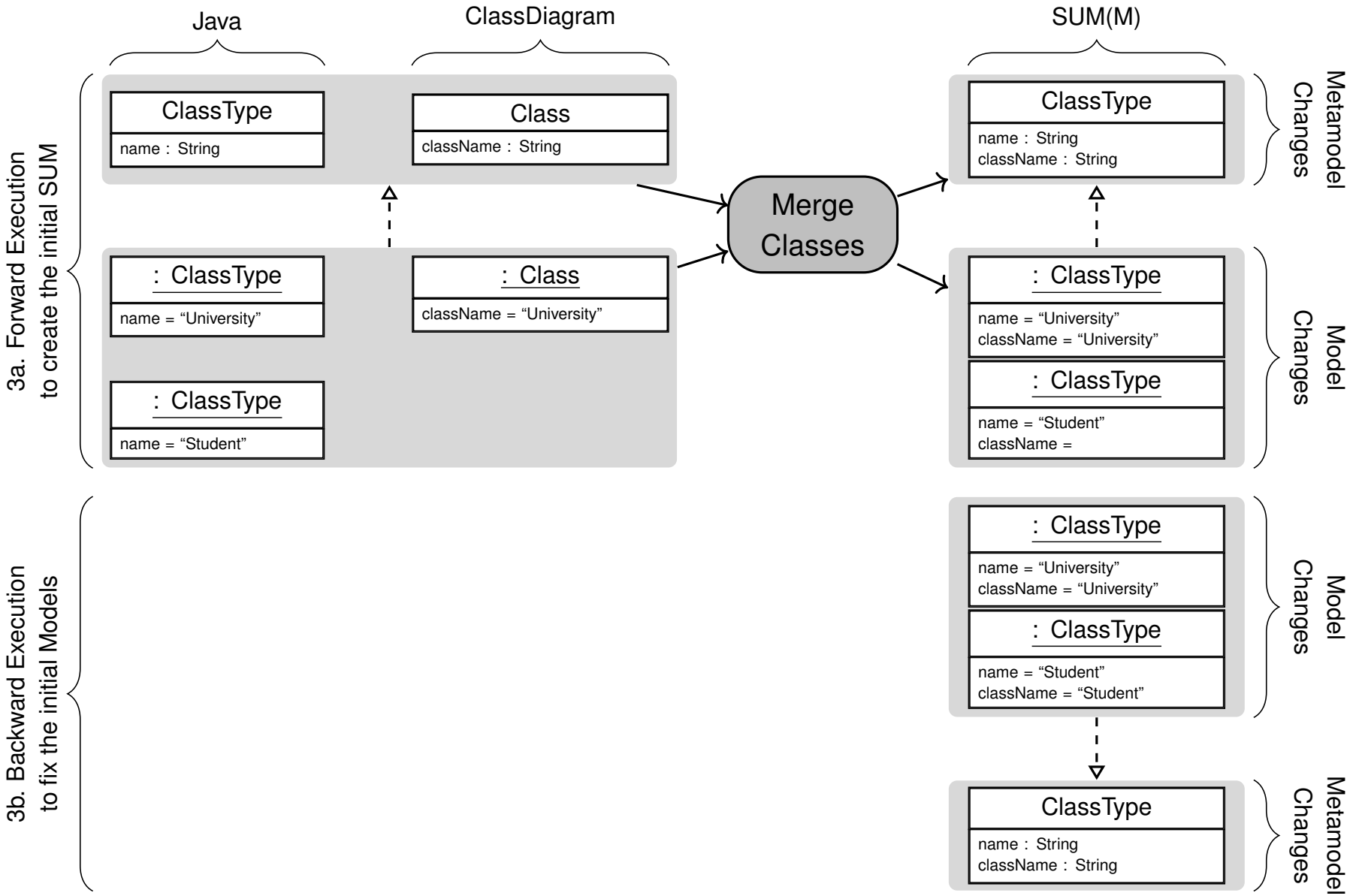

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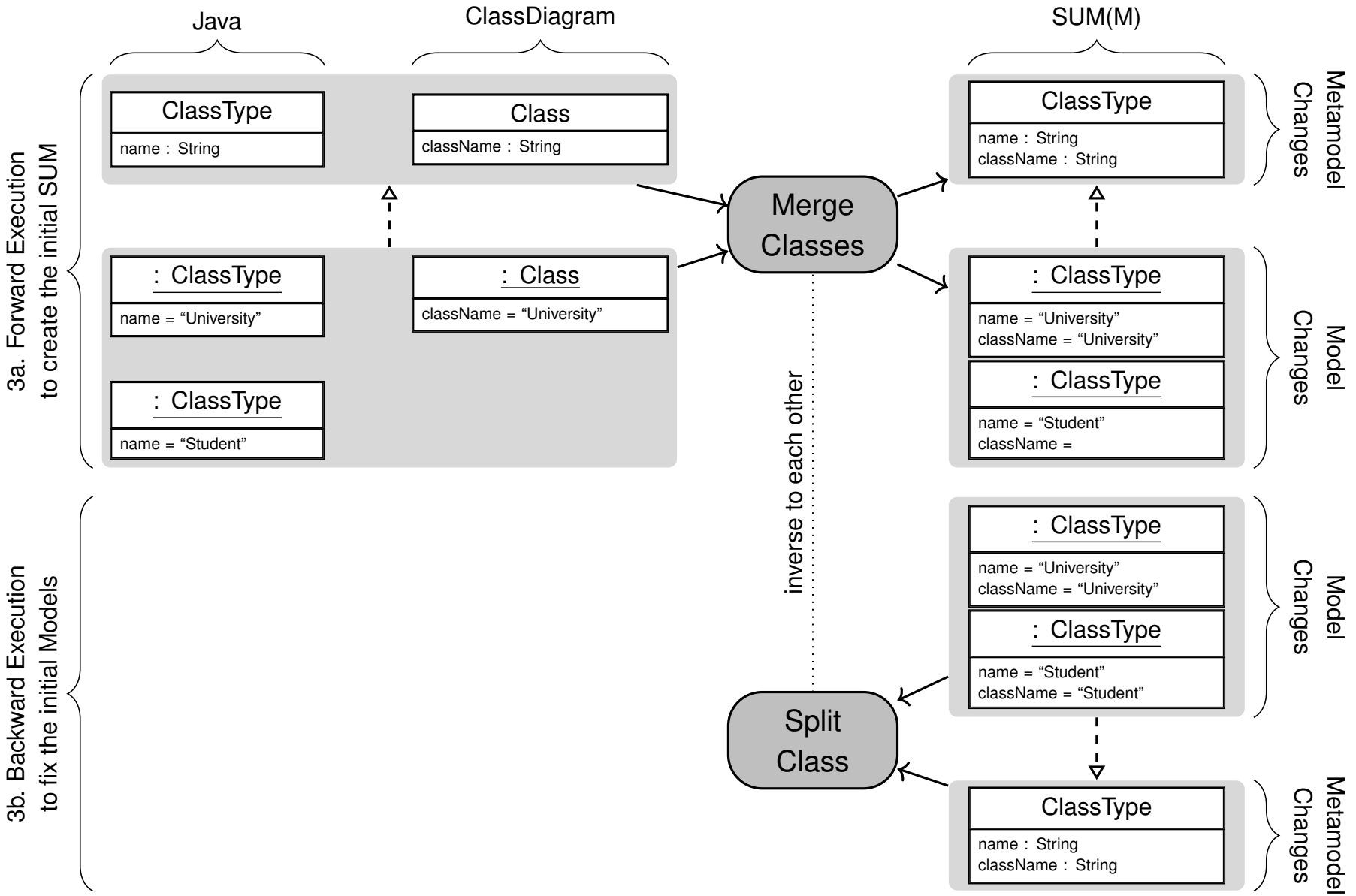

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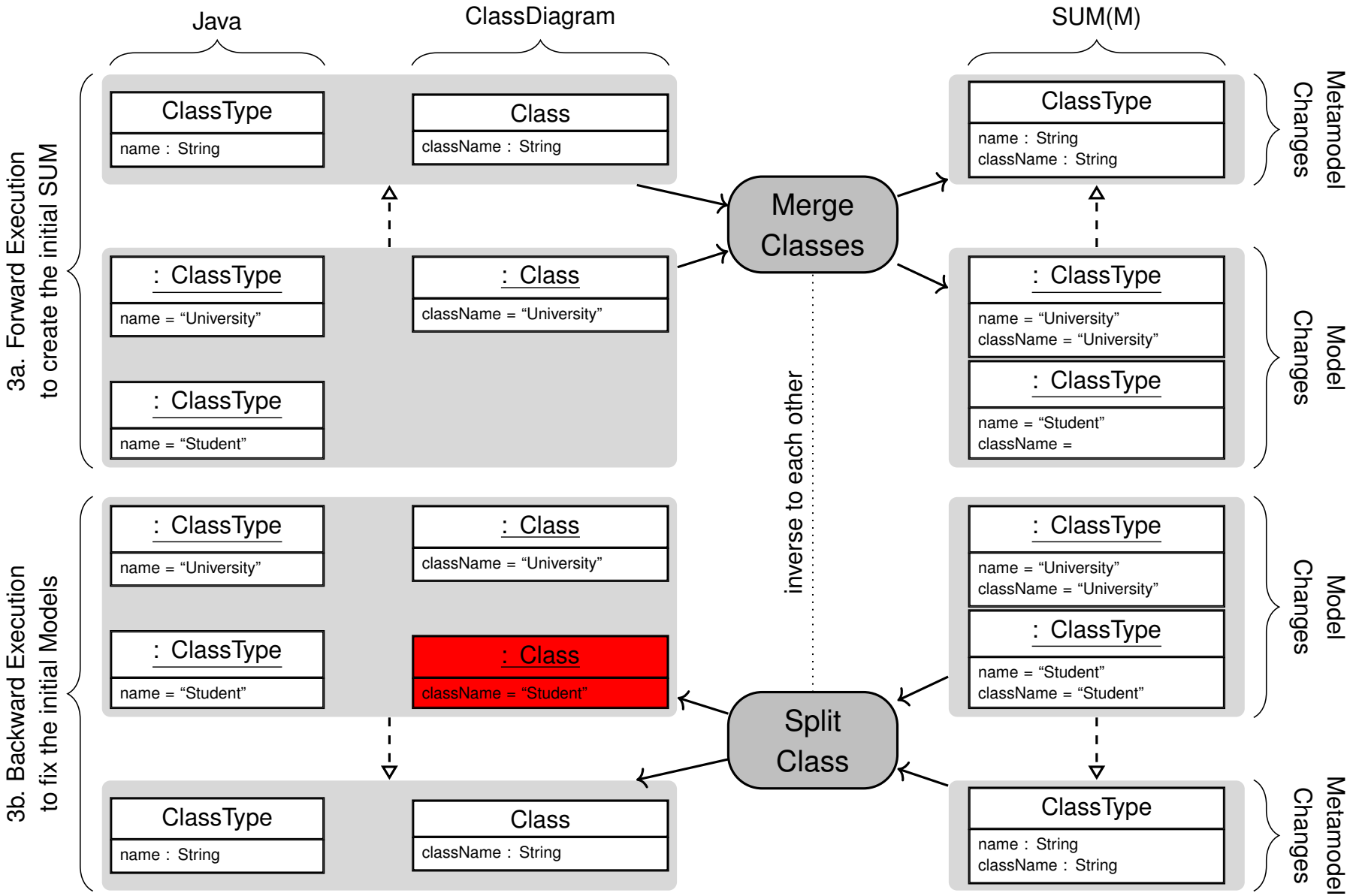

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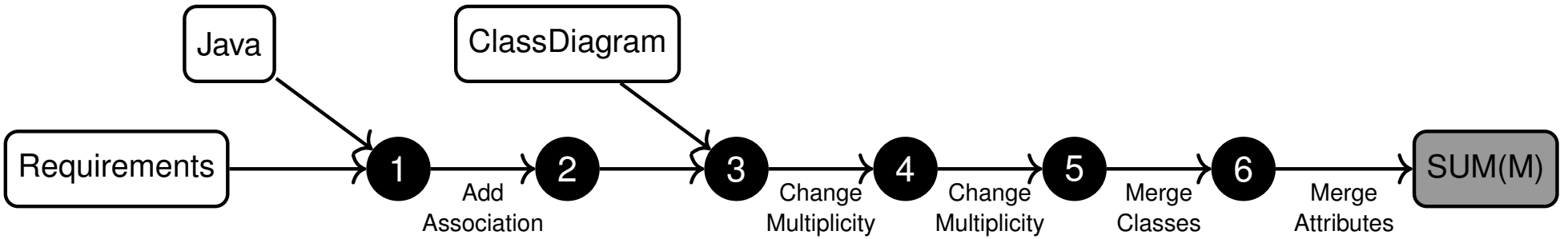

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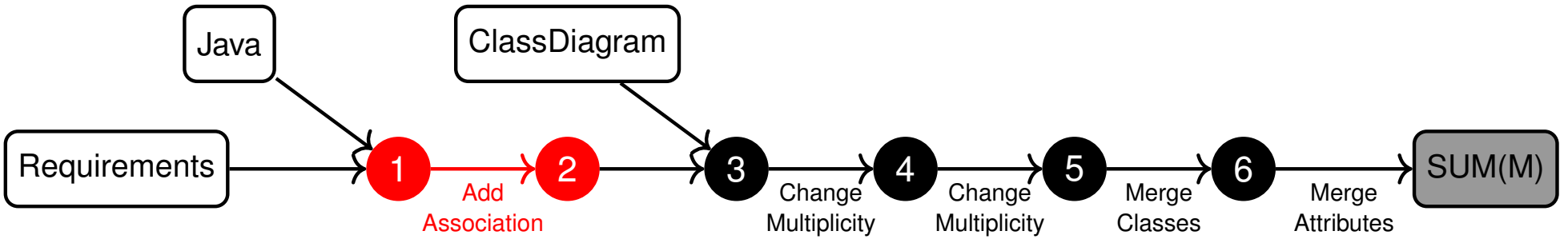

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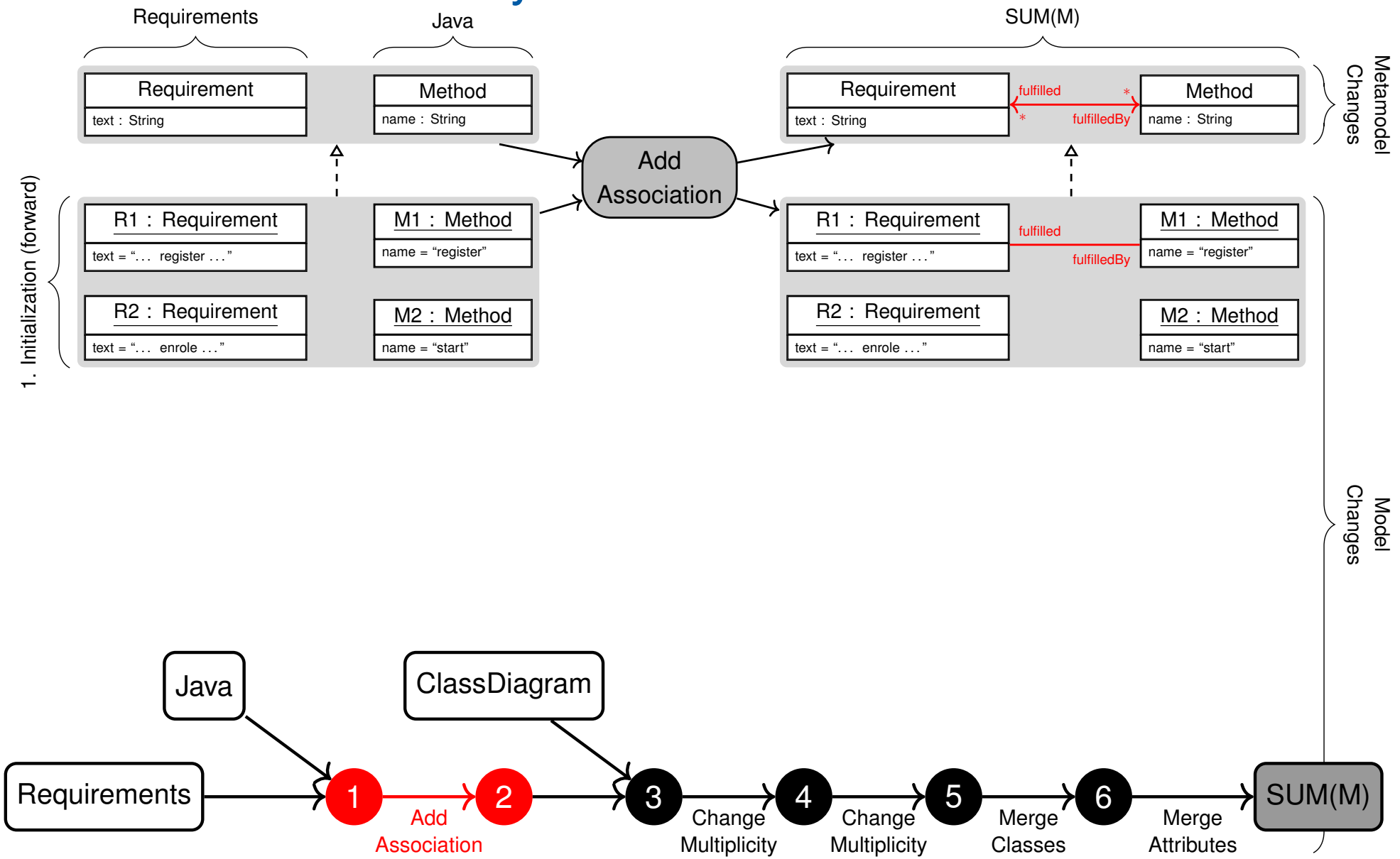

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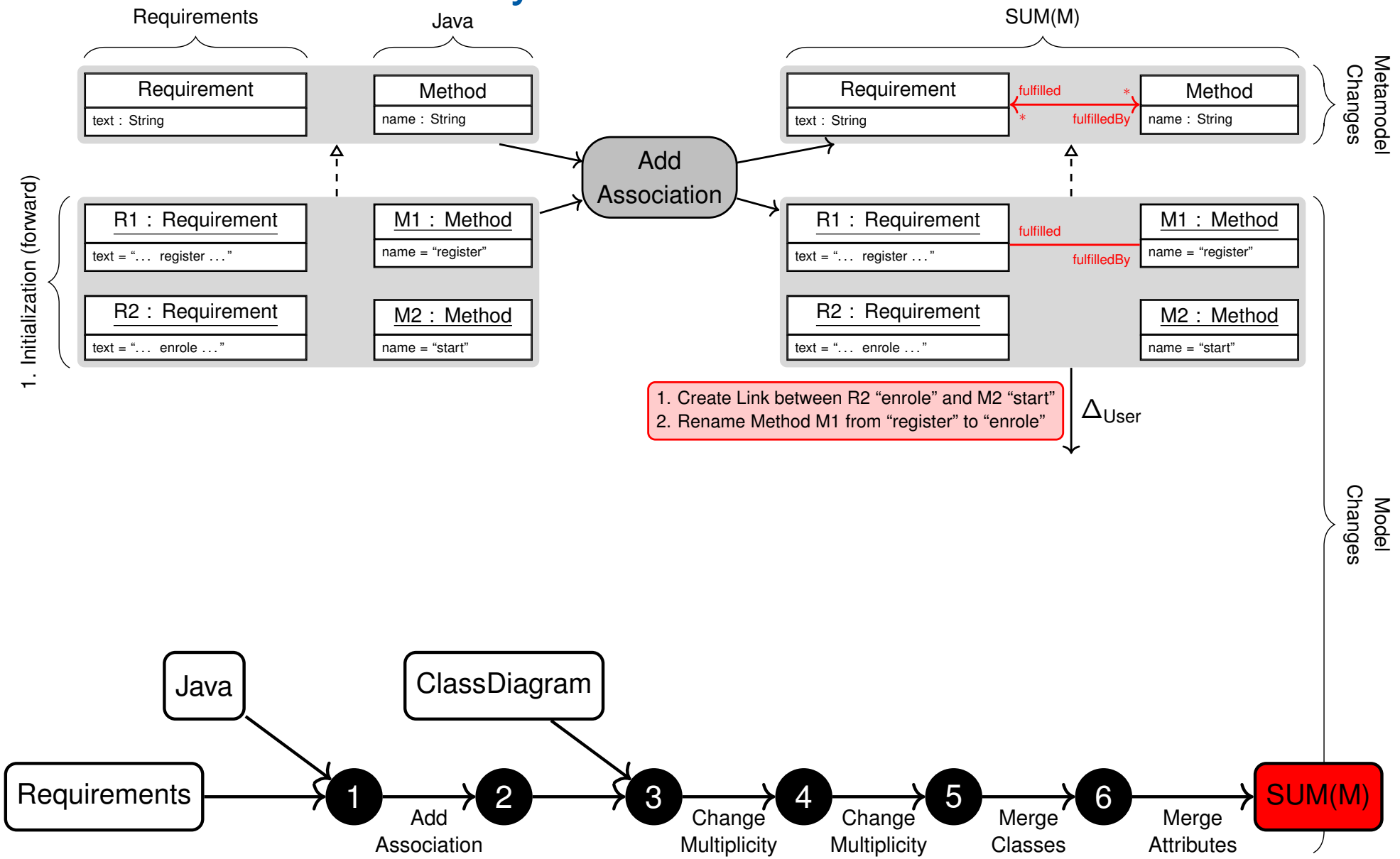

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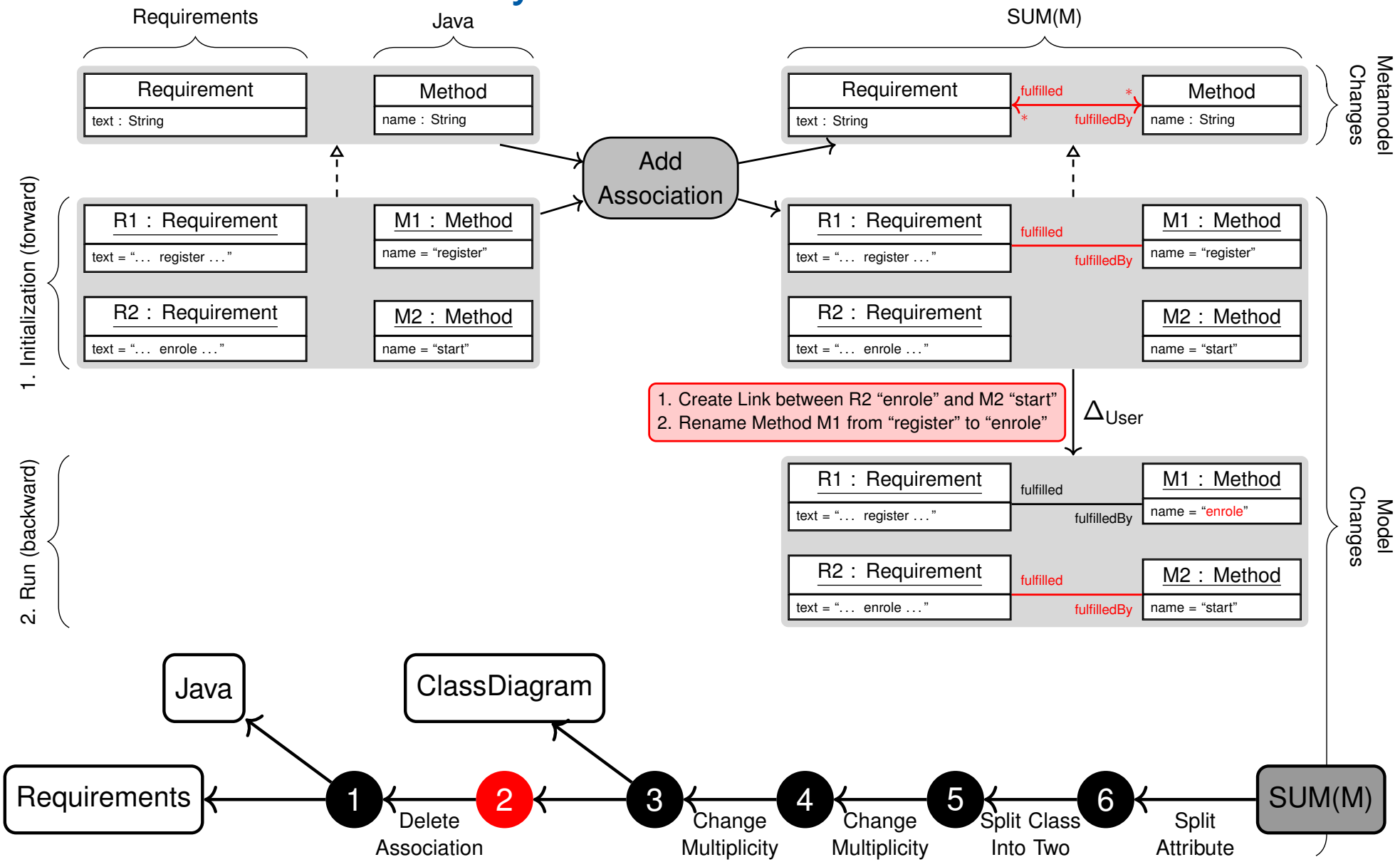

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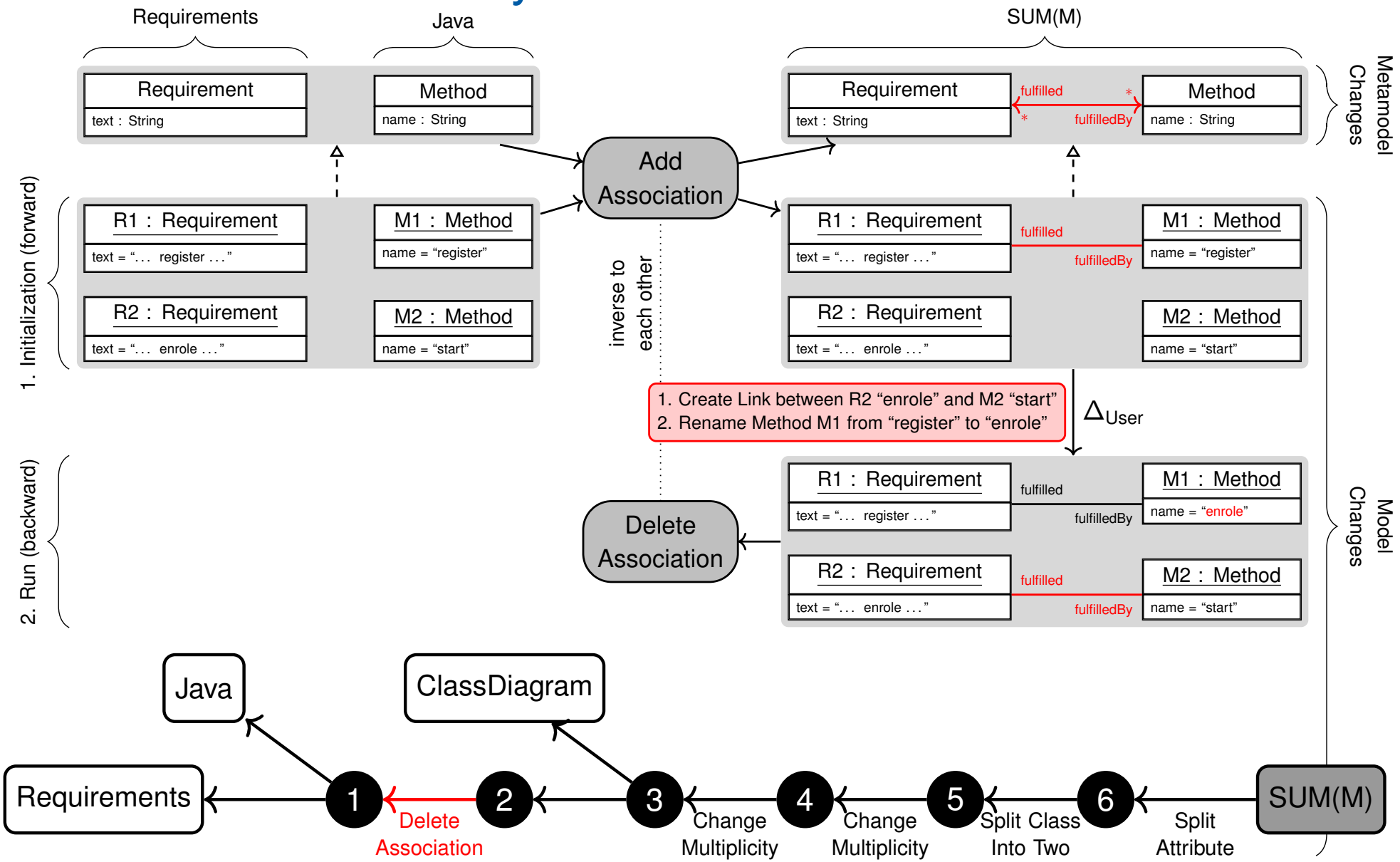

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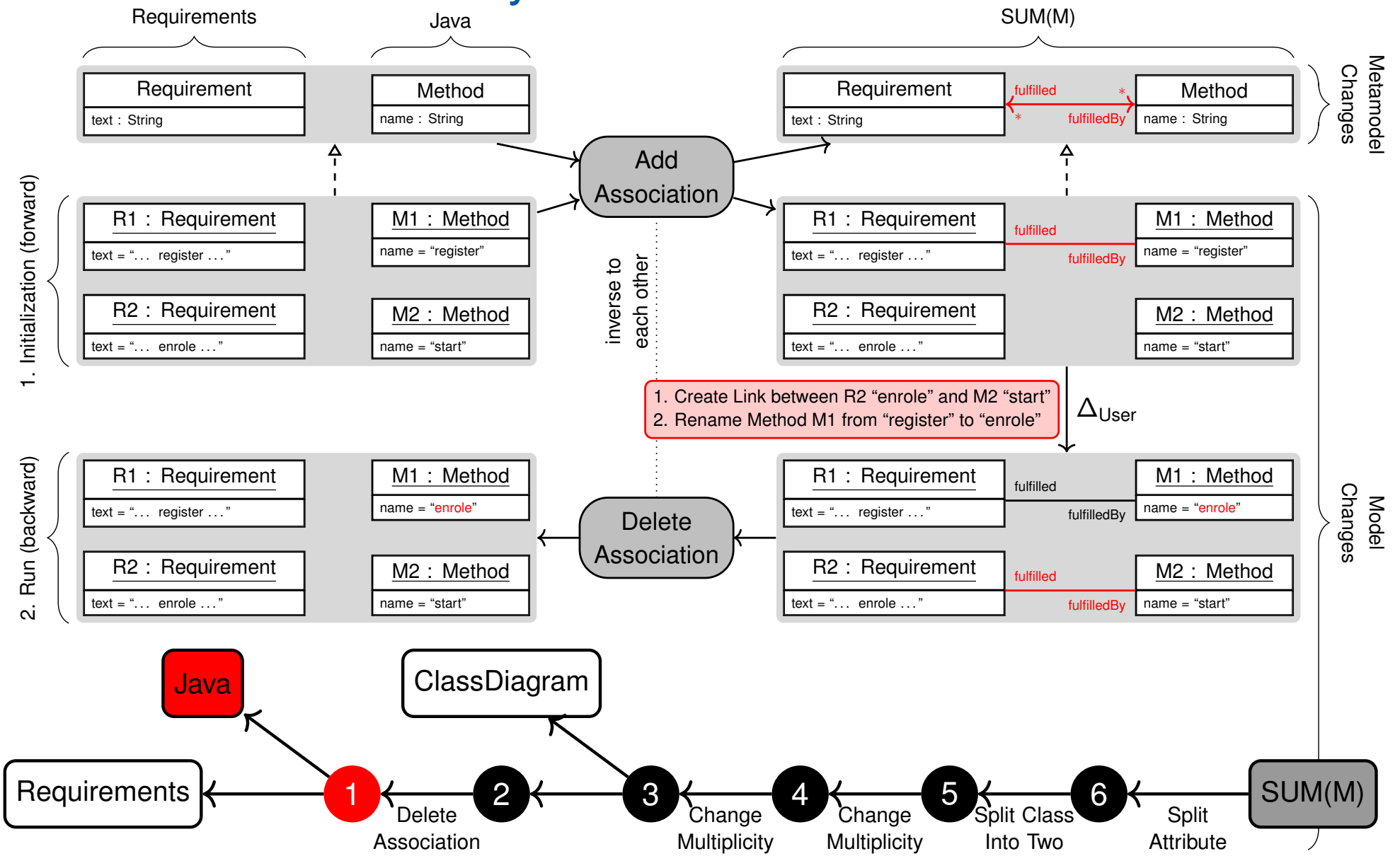

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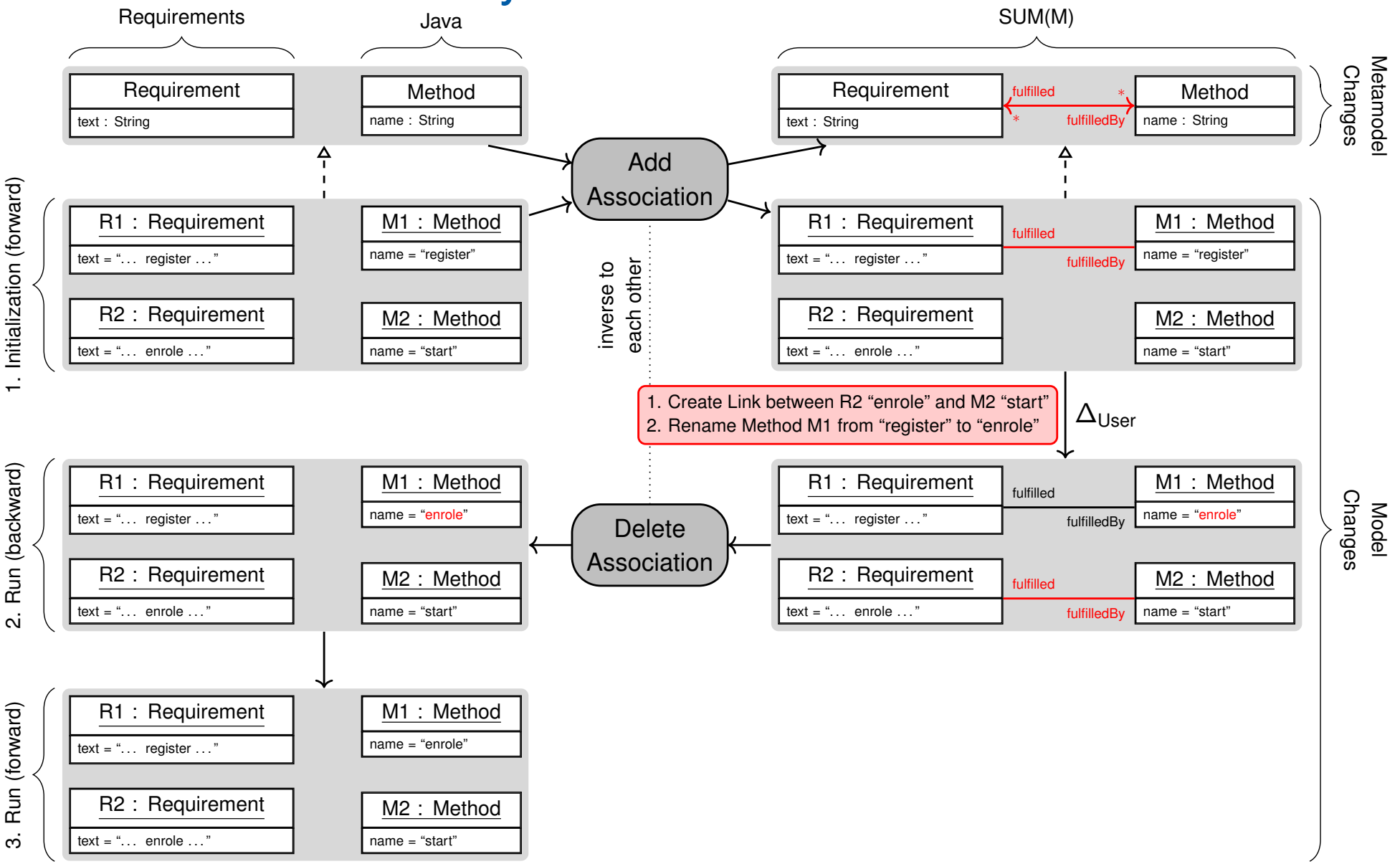

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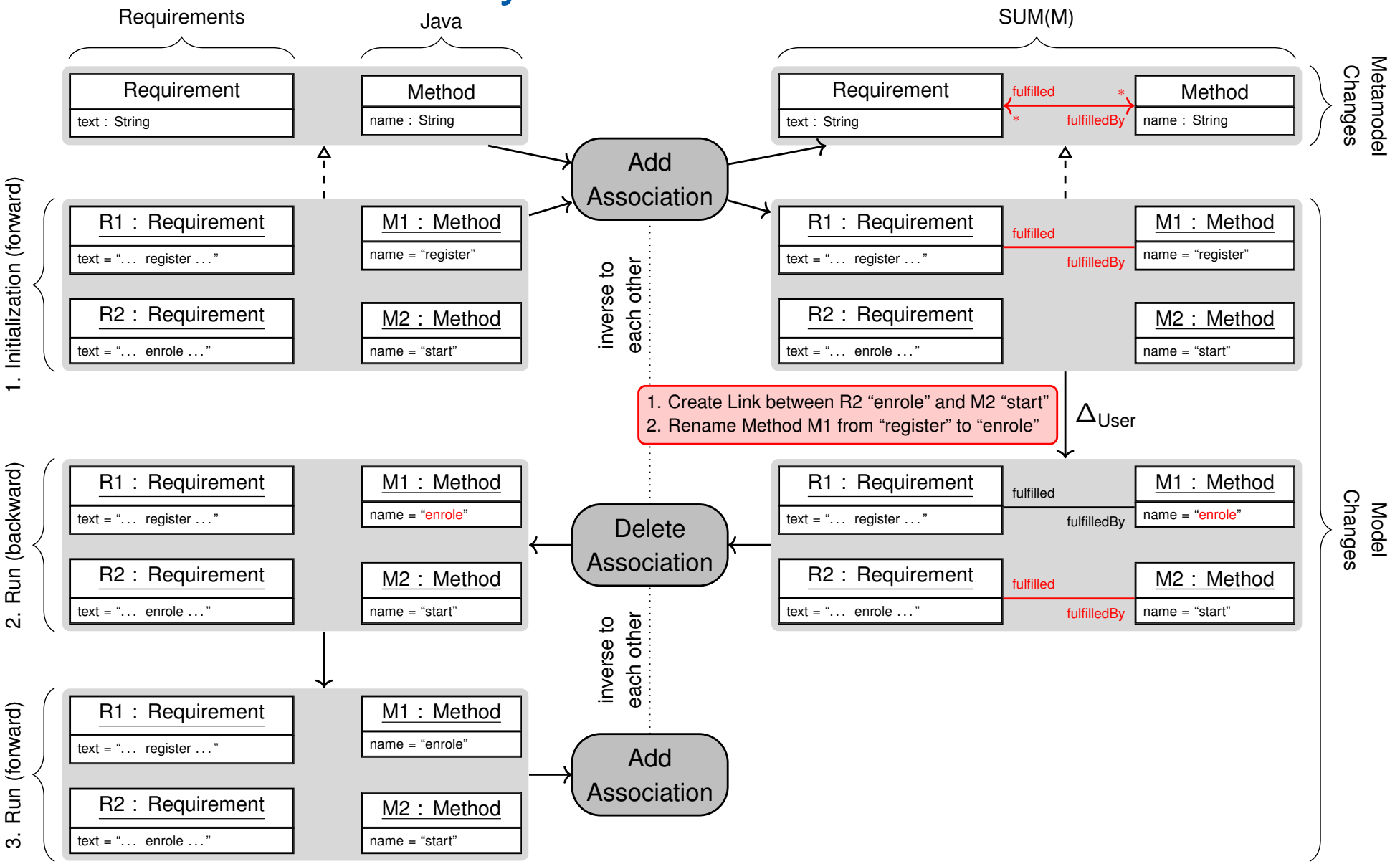

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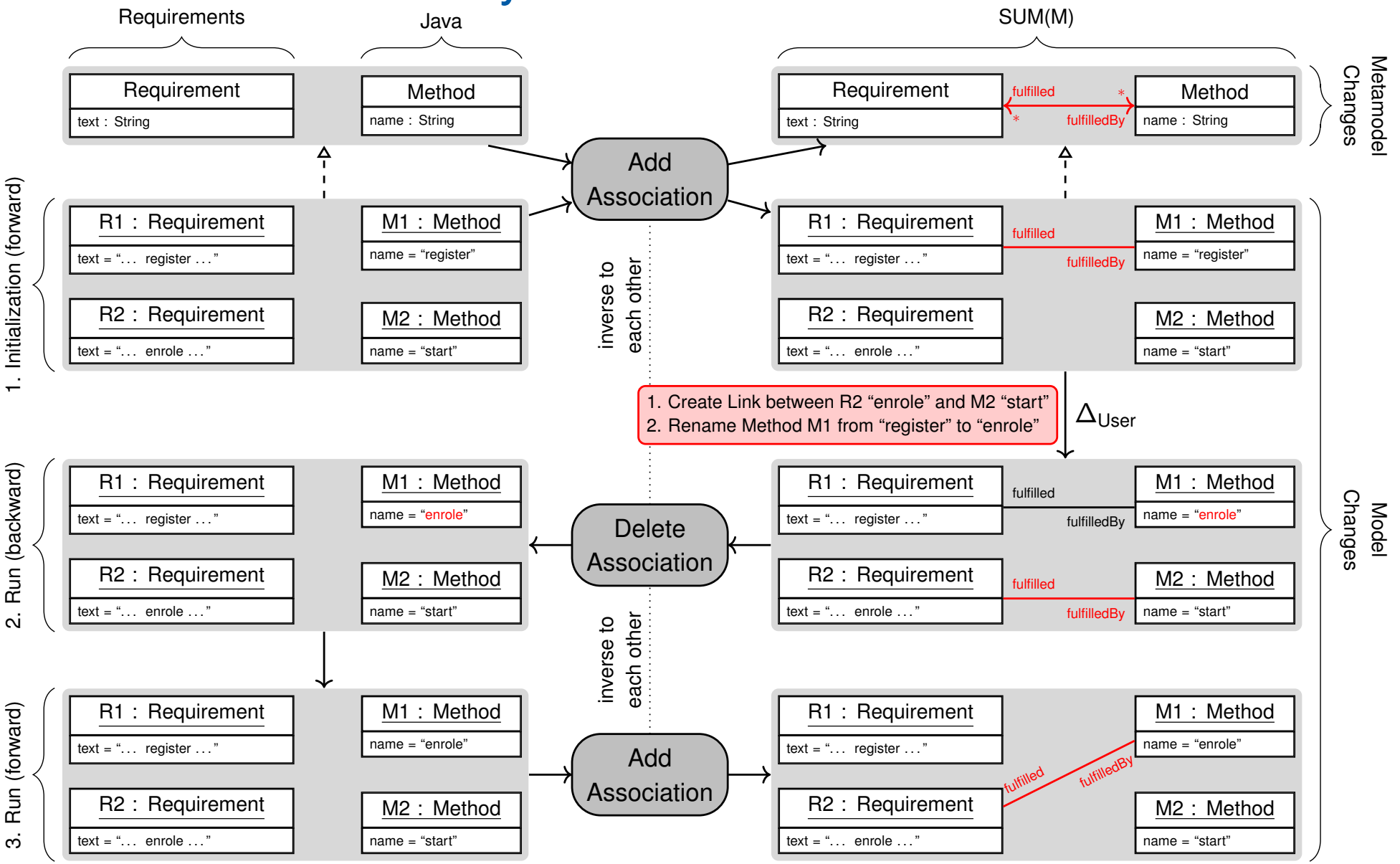
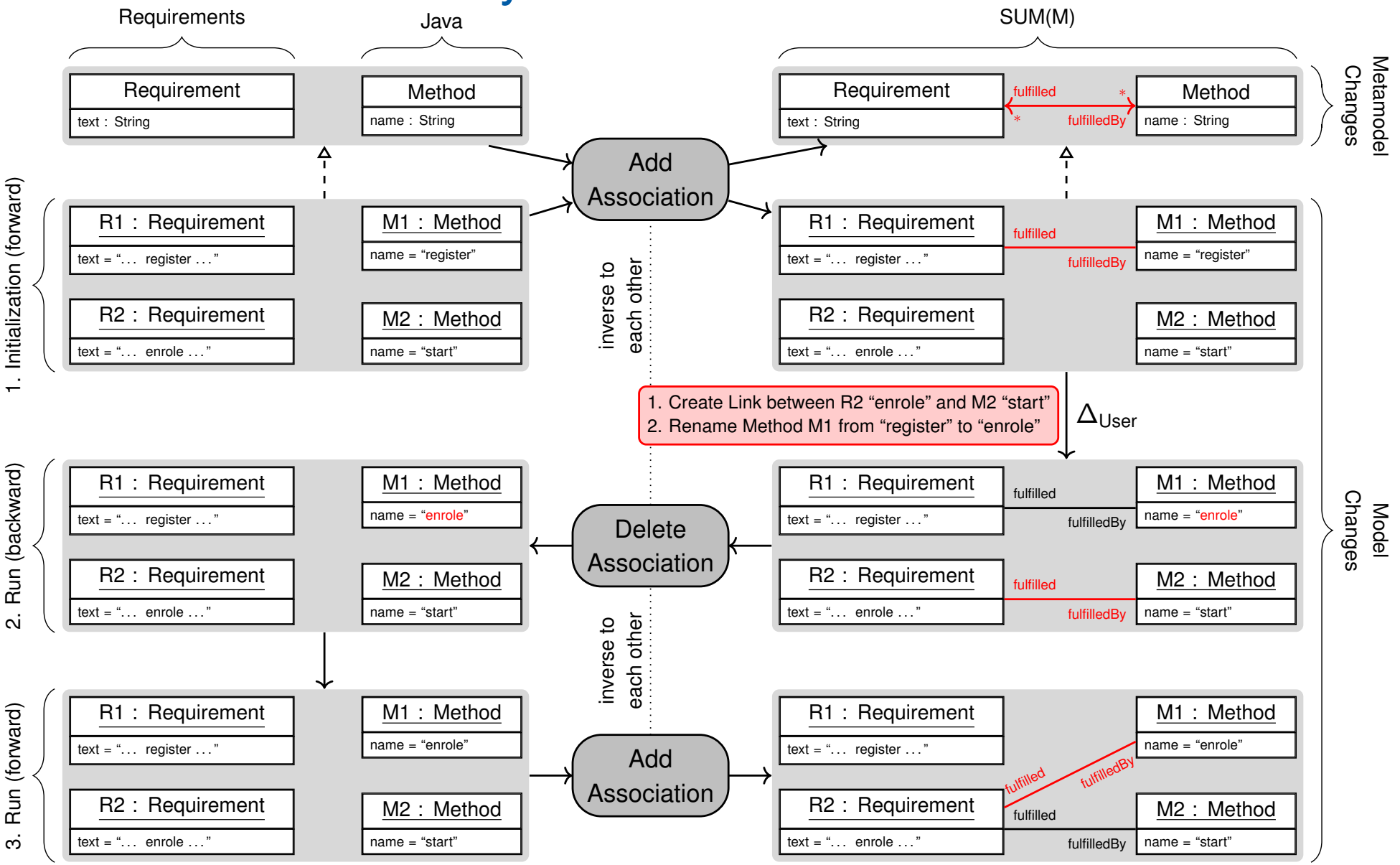
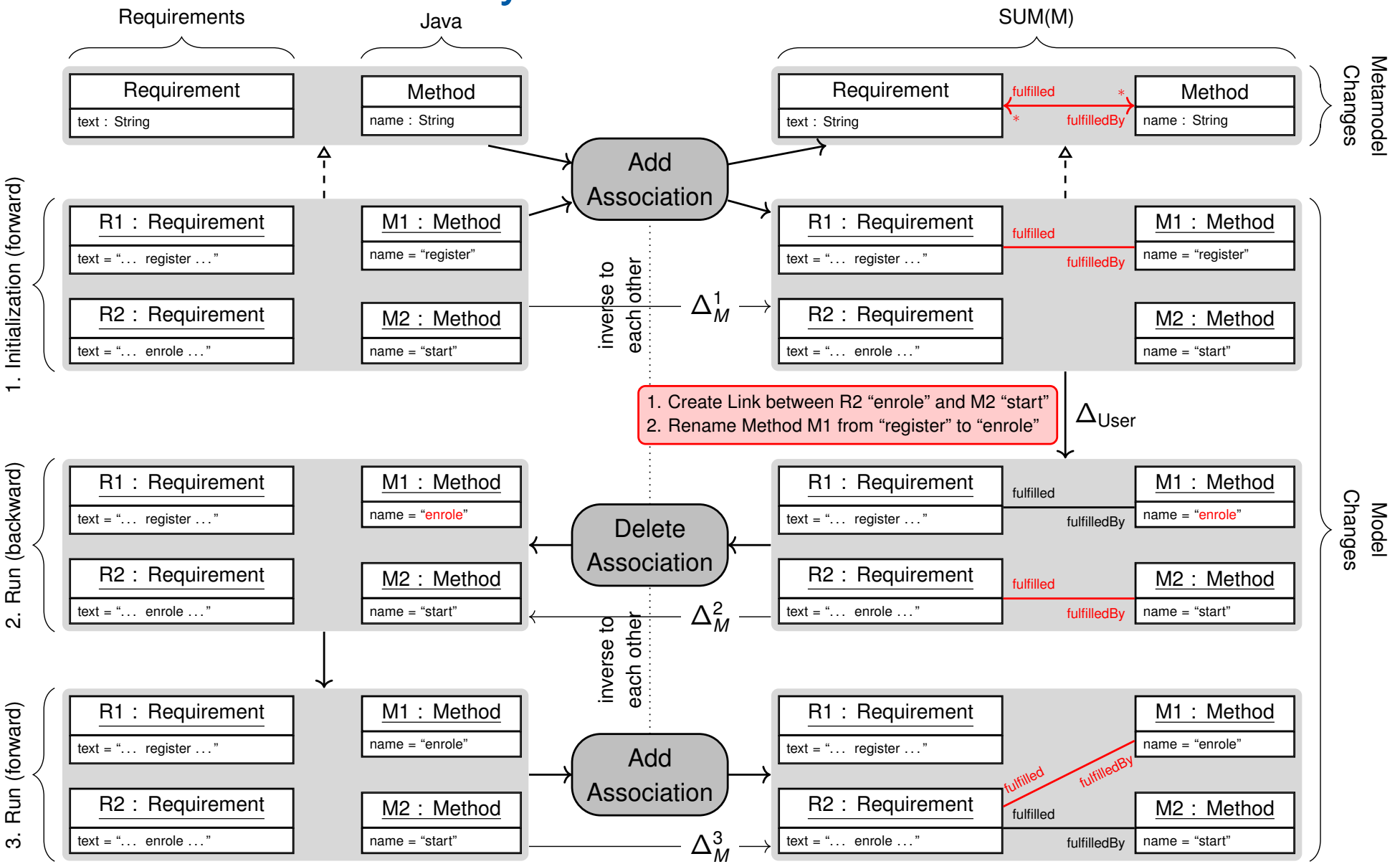


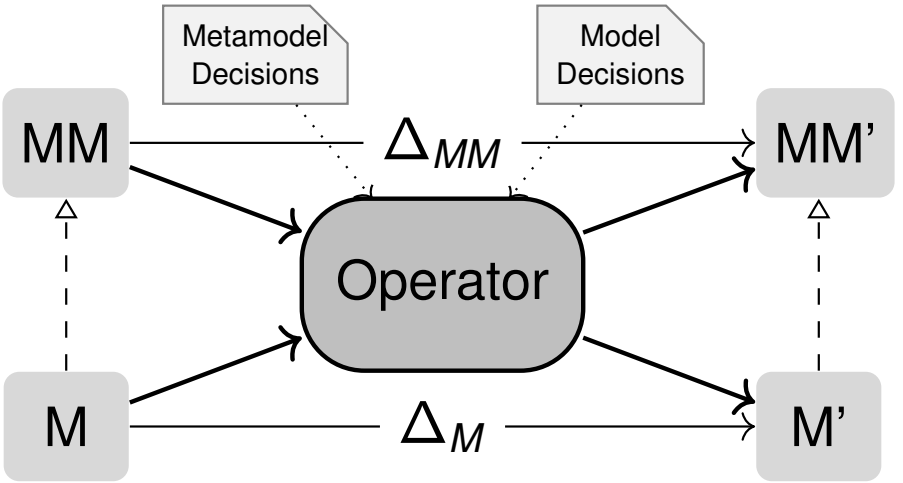
# 3. Consistency Assurance: Details



# 3. Consistency Assurance: Details



# Operators: Summary

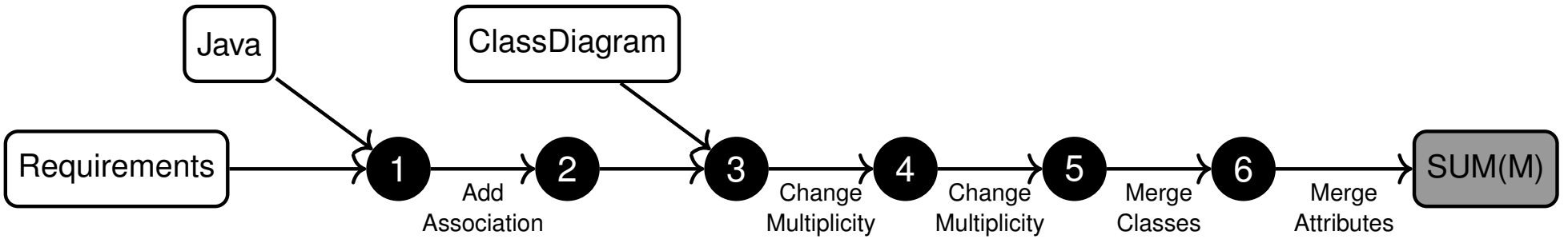



- **Metamodel Change** $\Delta_{MM}$:
  small Change in the Metamodel
- **Model Change** $\Delta_M$:
  handle Model-Co-Evolution (Coupled Operators [HVW11])
- Configurations by the Methodologist:
  - **Metamodel Decisions**: set Properties for wanted Metamodel Changes
  - **Model Decisions**: describe Model Changes for Consistency Rules
- **Bi-Directionality only for MM**: combine with inverse Operator
- currently 20 Operators implemented

# Summary

Operator-based bottom-up SUM-Approach for Model Consistency:

- Methodologist configures arbitrary, but stable Chain of configured Operators (once)
- User applies Changes and Model Consistency is ensured automatically by executing the Operator Chain
- $\rightarrow$ separated Models are migrated to projectional Views on the SUM



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