Model-based Mining of Software Repositories

Markus Scheidgen

Agenda

- *Mining Software Repositories* (MSR) and current approaches
- *srcrepo* – a model-based MSR system
  - *srcrepo* components and analysis process
  - a meta-model for *source code repositories*
  - gathering software metrics with an *OCL-like* internal Scala DSL
- **work in progress** - discussion of remaining problems and limitations

Relevant Research Fields

Mining Software Repositories (MSR)

The term *mining software repositories* (MSR) has been coined to describe a broad class of investigations into the examination of *software repositories*.

The premise of MSR is that empirical and systematic investigations of repositories will shed new light on the process of *software evolution*. [1]

Software Metrics

A software metric is a mathematical definition mapping the entities of a software system to numeric metrics values.

[...] to express features of software with numbers in order to facilitate software quality assessment. [2]

Reverse Engineering

Reverse engineering is the process of analyzing a subject system to (1) identify the system's components and their interrelationships and (2) create representations of the system in another form or at a higher level of abstraction [3]

Software Evolution Research (SER)

- (dis-)proving *Lehmann's Laws* of software evolution
- empirical investigations of software repositories through statistical analysis of software and software change metrics over the evolutionary cause of many software systems.

Model-based Mining Software Repositories (with *srcrepo*)

Overcoming **heterogeneity** and **accessibility** by raising the level of abstraction, while ensuring **scalability** and retaining meaningful **information depth**.

1. **H. Kagdi, M.L. Collard, J.I. Maletic:** *A survey and taxonomy of approaches for mining software repositories in the context of software evolution*; Journal of Software Maintenance and Evolution: Research and Practice; Vol.19/Nr.2/2007
2. **R. Lincke, J. Lundberg, W. Löwe**: *Comparing Software Metrics Tools;* 8th International Symposium on Software Testing and Analysis; 2008
3. **E.J. Chikofsky, J.H. Cross**: *Reverse engineering and design recovery: A taxonomy*; IEEE Software; Vol.7/Nr.1/1990

Contemporary Approaches to Large Scale MSR for SER

FLOSS Metrics [1]	Sourcerer [2]	Boa [3]
■ database for over 3000 open source software projects ■ contains data about all revisions ■ *Alitheia*, multiple *version control systems* (VCS), but only text-based metrics ■ not only *source code repositories* (SCR) via VCS, also issue-tracking systems, mailing-lists, etc.	■ database and searchable index of declarations from over 4000 Java software projects ■ tracks only release revisions ■ metrics based on declarations (classes, methods, fields, etc., e.g. CK-metrics), but not based on actual implementations (e.g. McCabe, Halstead)	■ *domain specific language* (DSL) for mining meta-data in ultra-large software repositories ■ only tracks VCS meta-data, e.g. *"How many revisions are there in all Java projects using SVN?"*

	Scalability	Heterogeneity	Accessibility	Information Depth
	■ a project ■ large scale: multiple related projects, e.g. Apache, Eclipse ■ ultra-large scale: 100k+ unrelated projects with varying quality [1,2,3]	■ abstraction from VCS [1,2,3] ■ abstraction from programming language: only meta-data [3] or text [1]	■ programming ■ database with index [1,2] ■ DSL [3]	■ all revisions [1,3], sample revisions [2] ■ meta-data [3] ■ text [1] ■ declarations [2]

1. **G. Gousios, D. Spinellis:** *Alitheia core: An extensible software quality monitoring platform*; Proceedings of the 31st International Conference on Software Engineering; 2009
2. **E. Linstead, S. Bajracharya, T. Ngo, P. Rigor, C. Lopes, P. Baldi.**: *Sourcerer: mining and searching internet-scale software repositories;* Data Mining and Knowledge Discovery; Vok.18/Nr.2/2009
3. **R. Dyer, H.A. Nguyen, H. Rajan, T.N. Nguyen**: *Boa: A Language and Infrastructure for Analyzing Ultra-Large-Scale Software Repositories;* Proceedings of the 2013 International Conference on Software Engineering; 2013

Goals and Hypothesis

	Scalability	Heterogeneity	Accessibility	Information Depth
	▪ a project ▪ large scale: multiple related projects, e.g. Apache, Eclipse ▪ ultra-large scale: 100k+ unrelated projects with varying quality [1,2,3]	▪ abstraction from VCS [1,2,3] ▪ abstraction from programming language: only meta-data [3] or text [1]	▪ programming ▪ database with index [1,2] ▪ DSL [3]	▪ all revisions [1,3], sample revisions [2] ▪ meta-data [3] ▪ text [1] ▪ declarations [2]

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goals	■ cluster- (batching) and cloud- (Map/Reduce)- computing support ■ distributable databases	■ common meta-model for VCSs ■ meta-models for programming languages ■ common meta-model for metrics	■ internal DSL: DSL + programming with models ■ common modeling framework ■ existing tools/ frameworks	■ all revisions ■ *abstract syntax trees* (AST) ■ differences between revisions (e.g. metrics on adaptations and refactorings)
hypothesis	■ distributable model persistence ■ distributed processing of models	■ abstraction for different VCSs exists ■ abstraction regarding metrics for diff. progr. languages exists ■ abstraction for diff. languages exists	■ is there a reasonable programming abstraction for gathering metrics/ change metrics	

srcrepo – Components and Process

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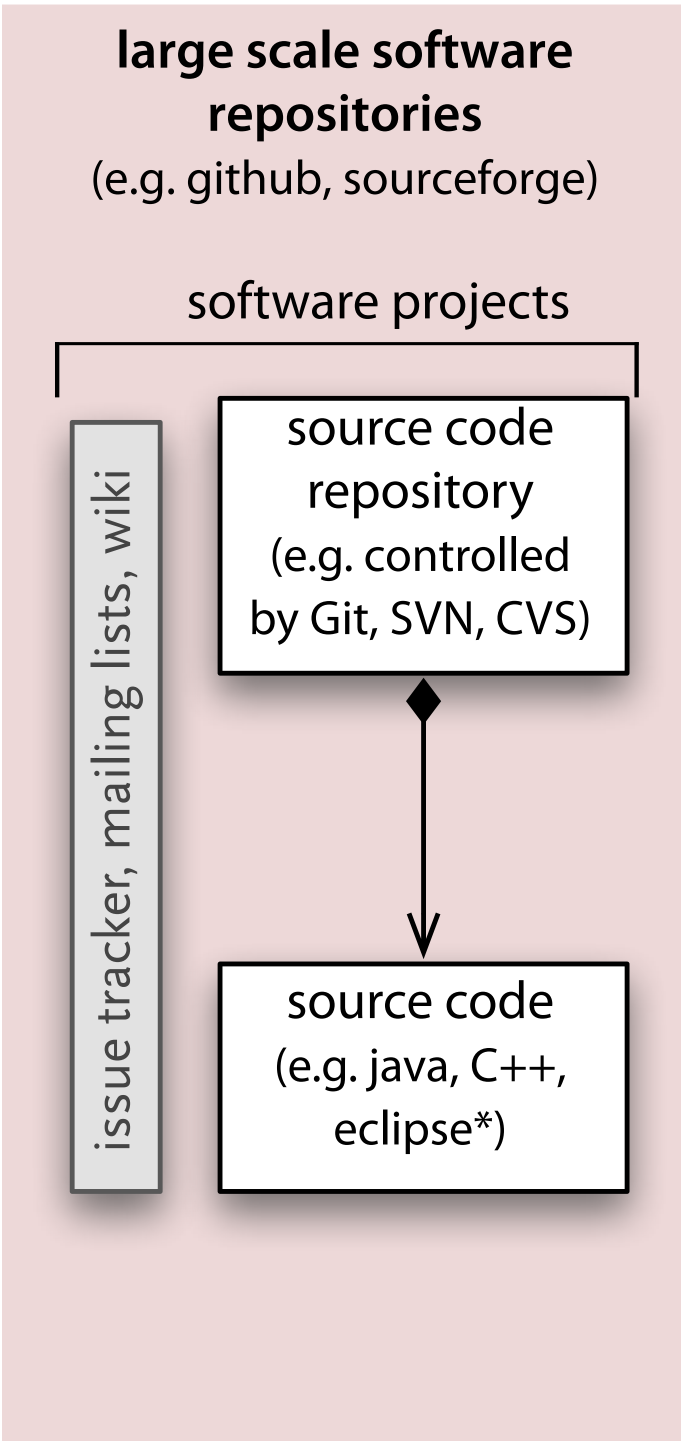
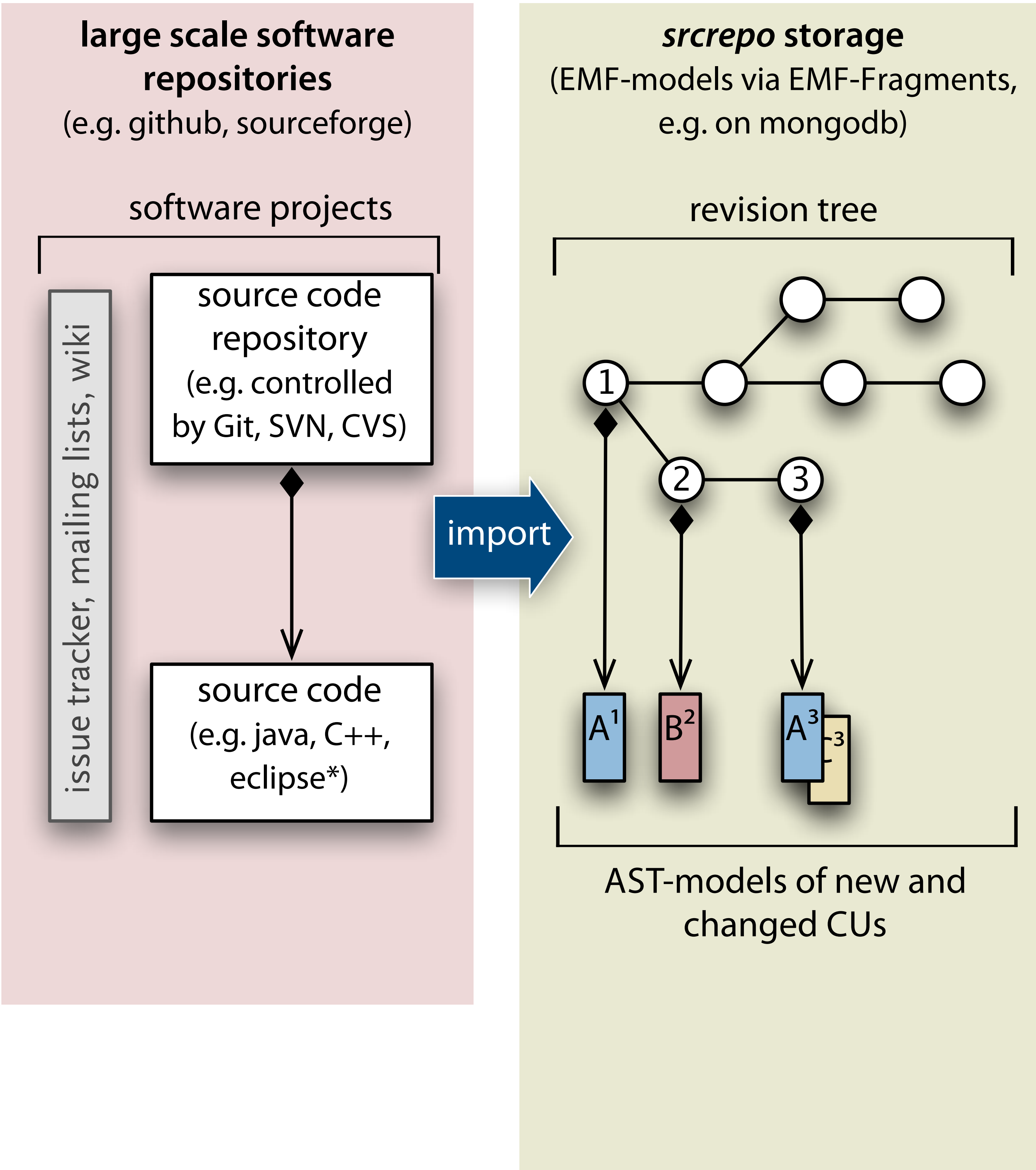
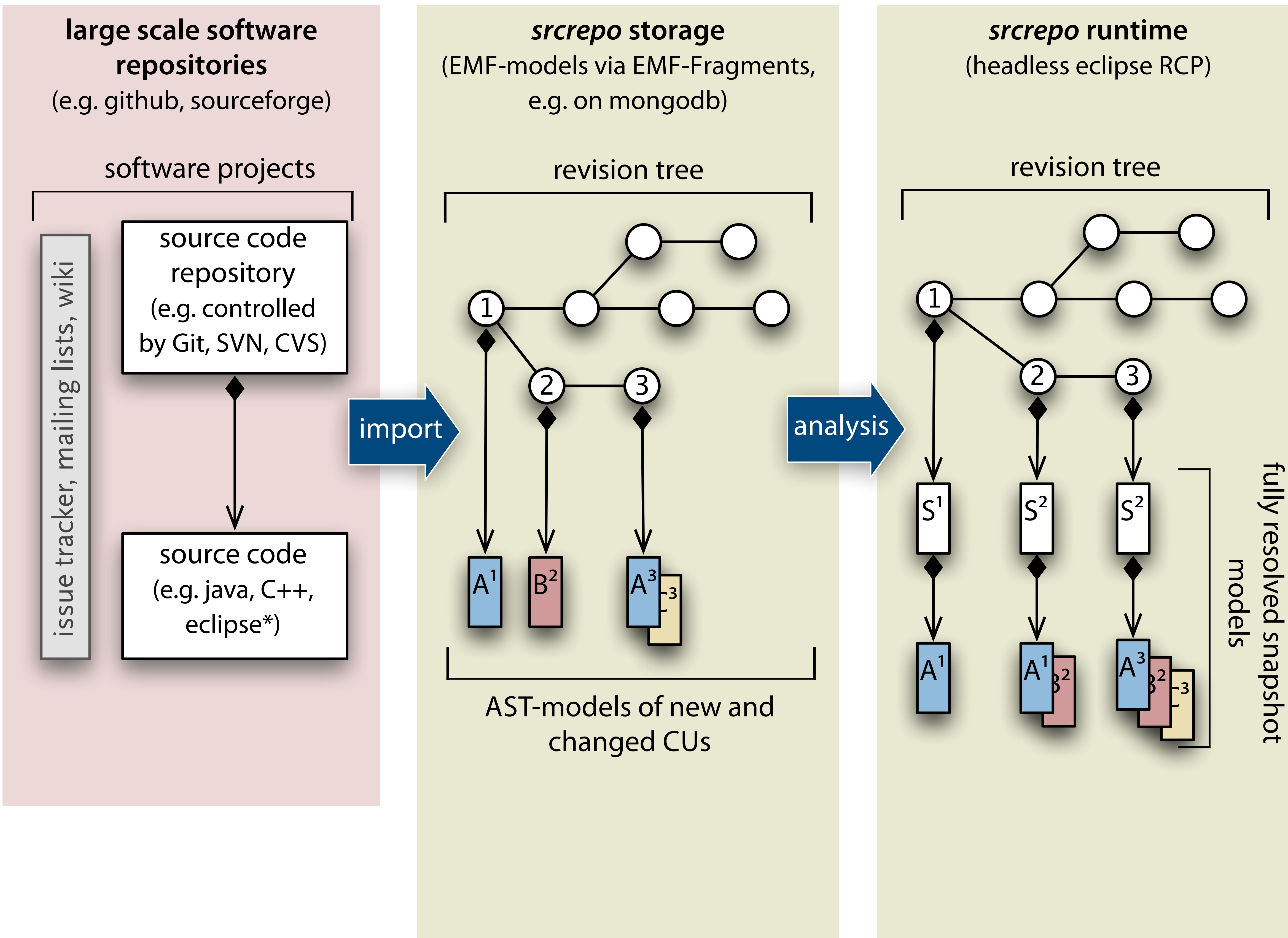


srcrepo – Components and Process



srcrepo – Components and Process



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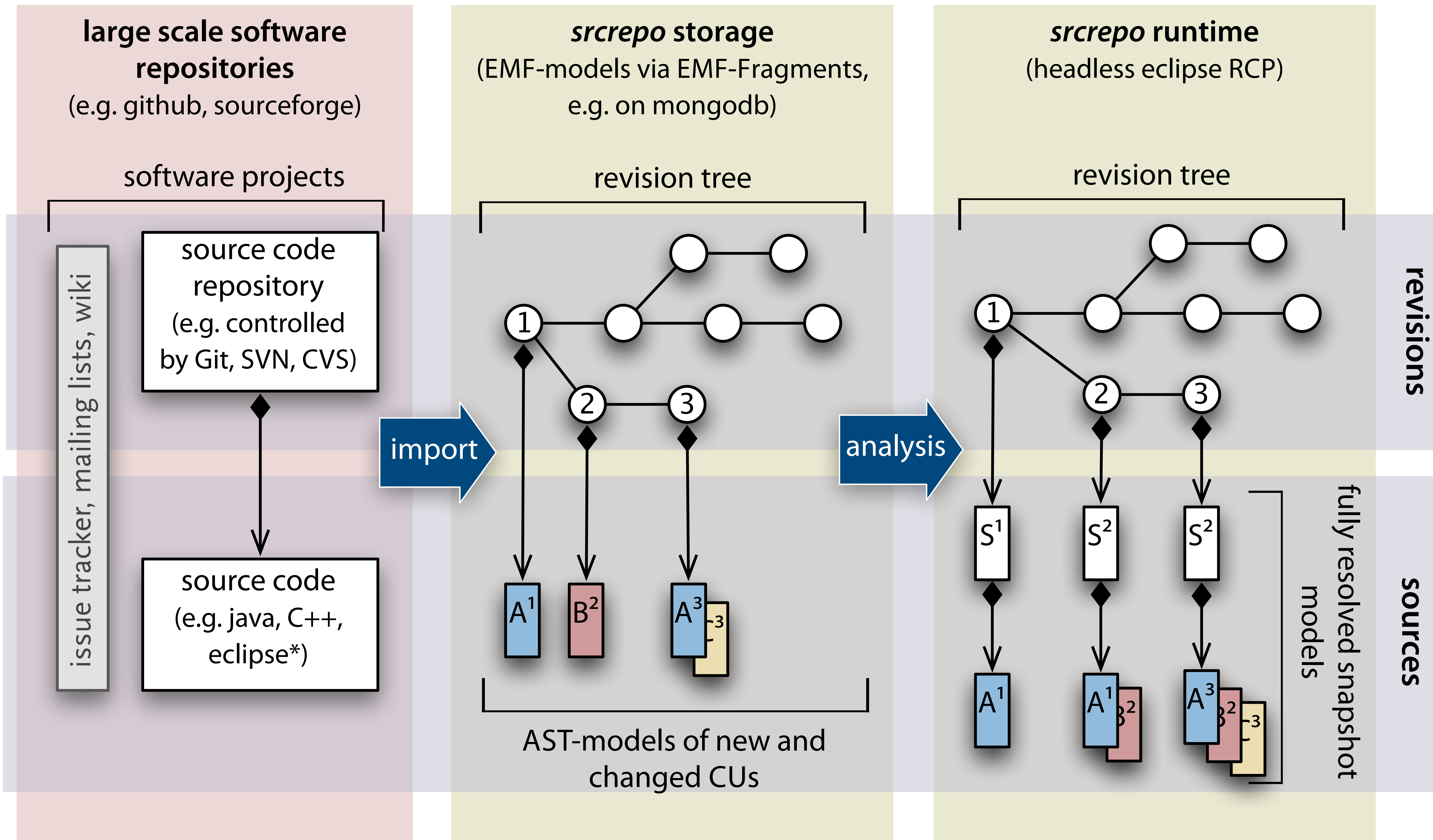

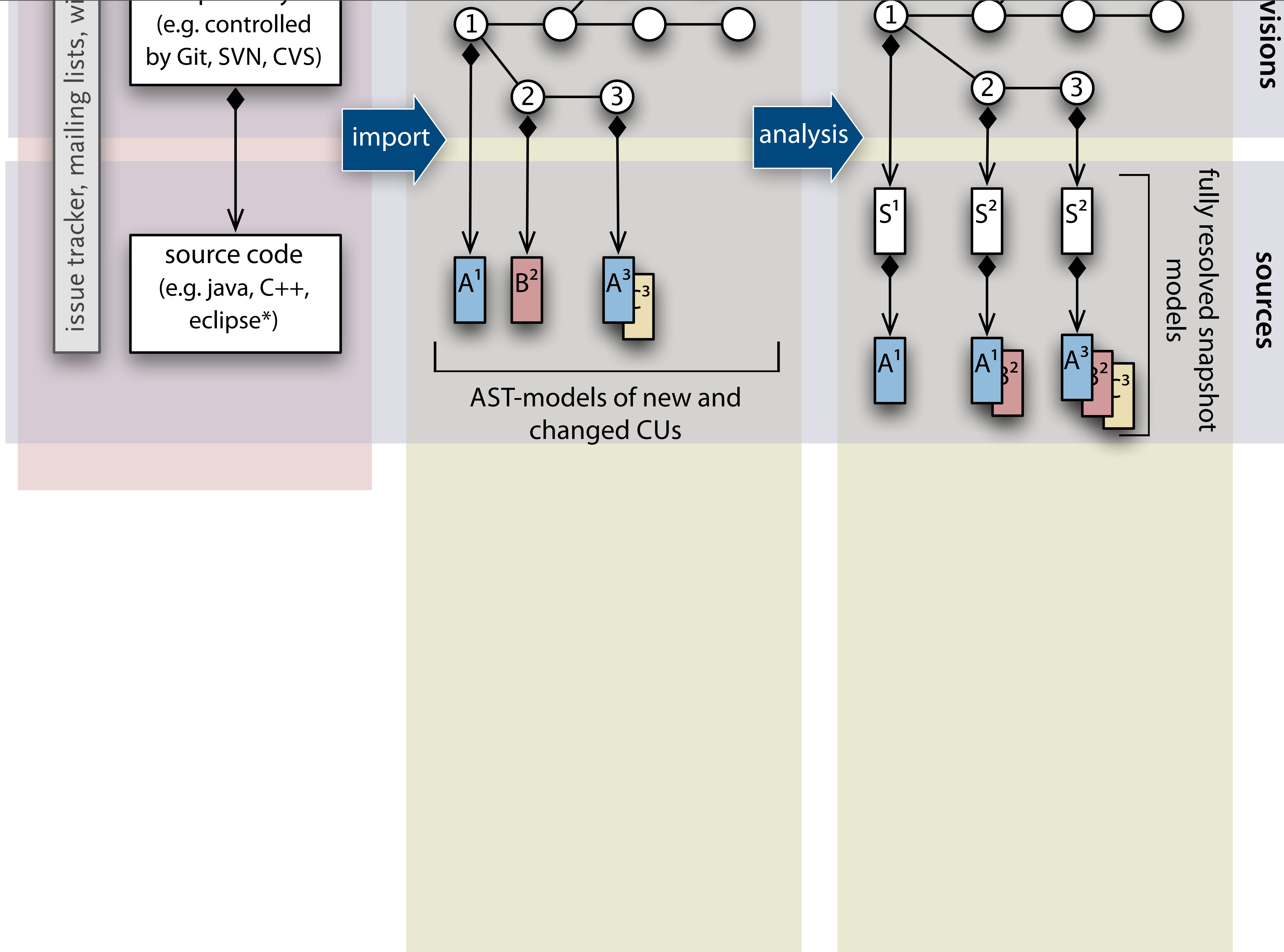
issue tracker, mailing lists, wi
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by Git, SVN, CVS)
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(e.g. java, C++,
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AST-models of new and
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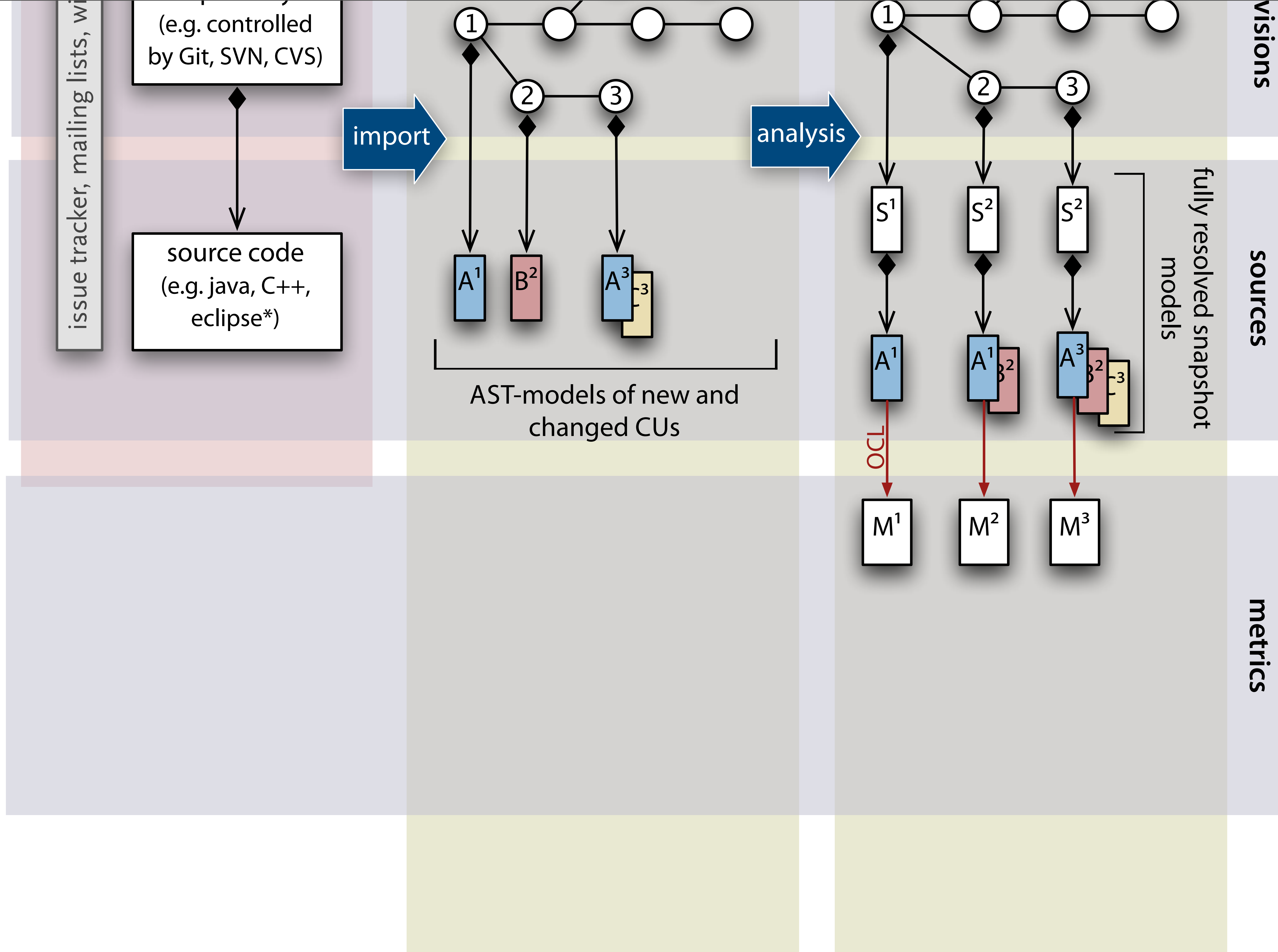

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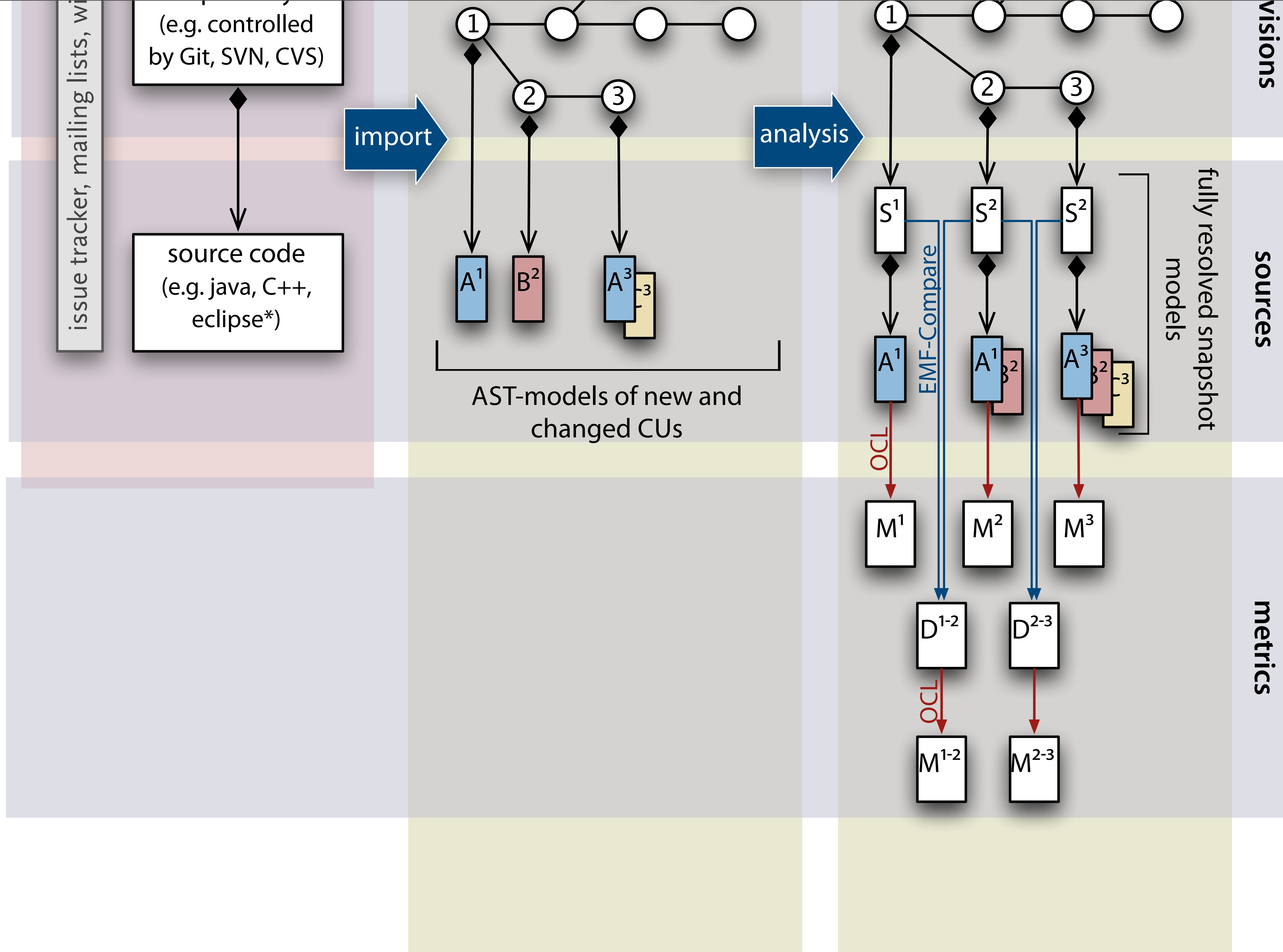
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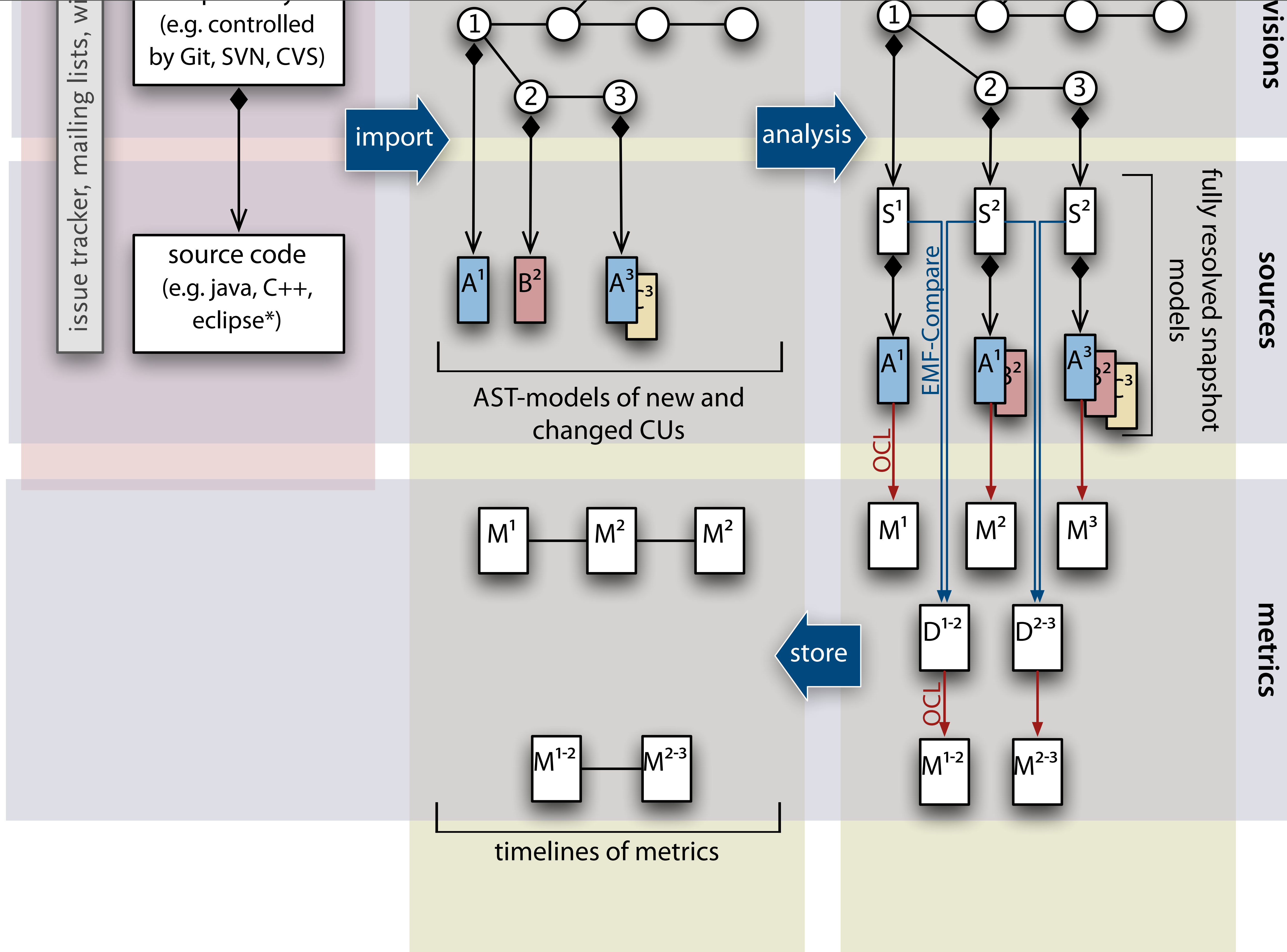
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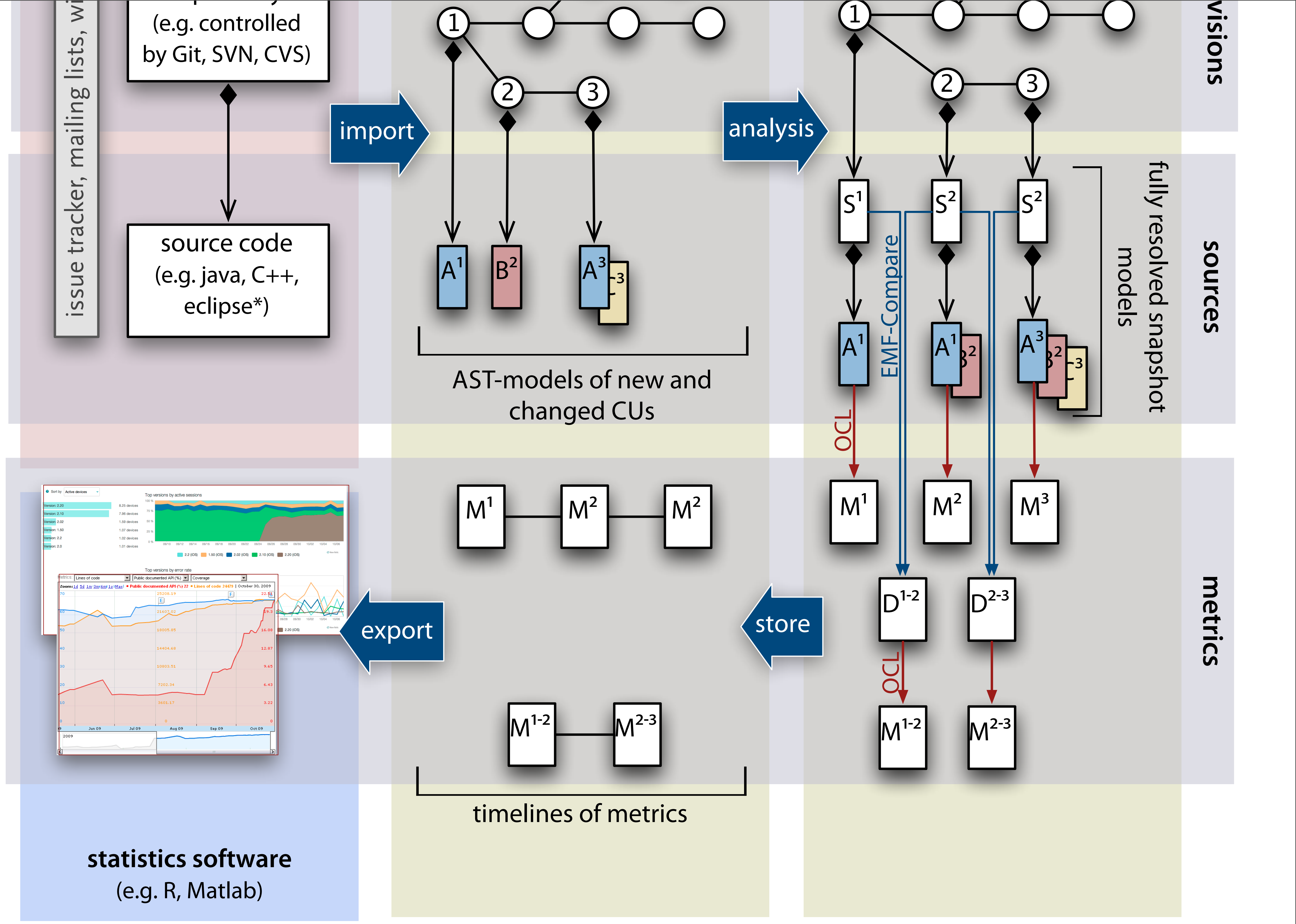
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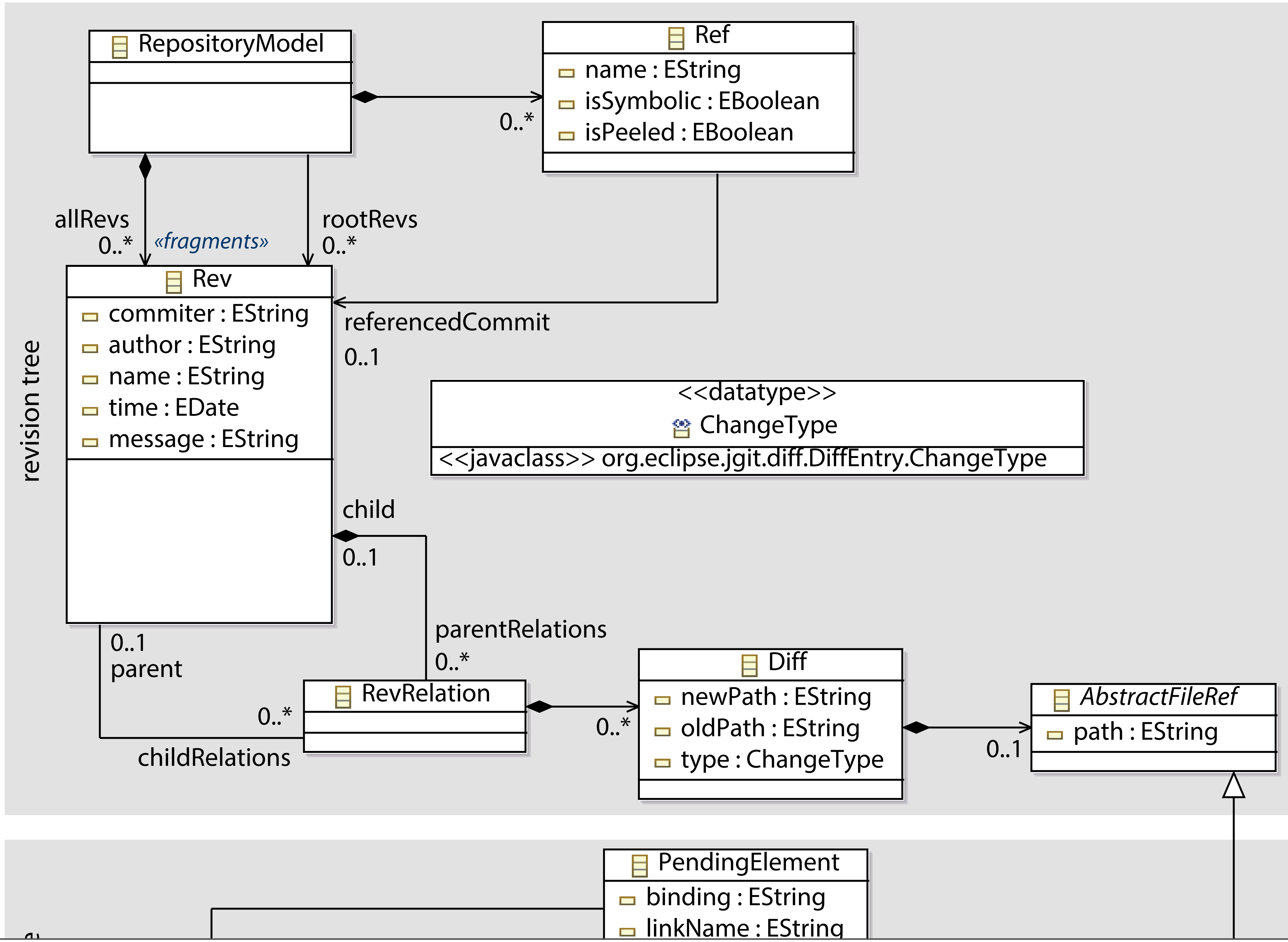
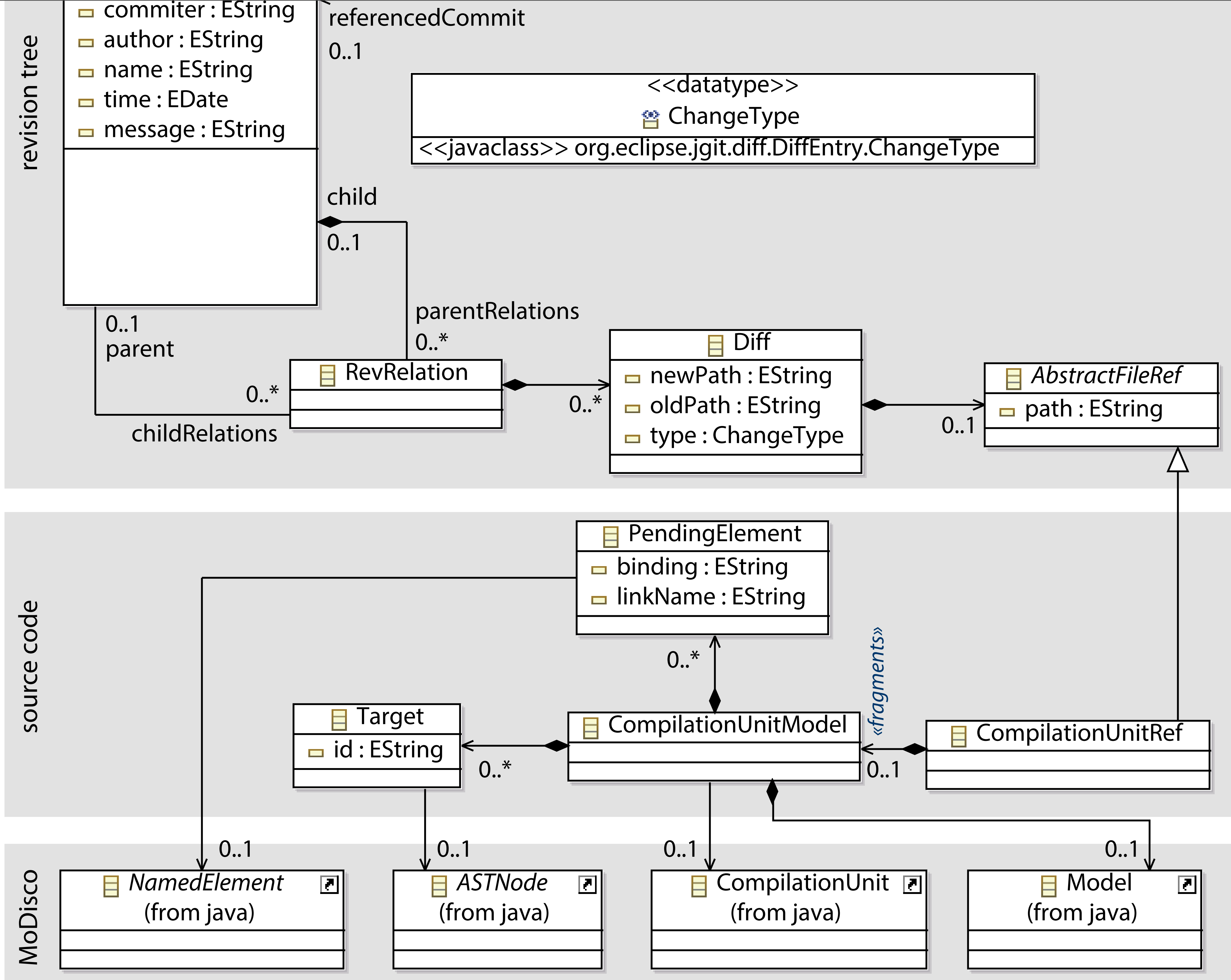
timelines of metrics
statistics software
(e.g. R, Matlab)

A Meta-Model for Source Code Repositories




revision tree
commiter : EString
author : EString
name : EString
time : EDate
message : EString
referencedCommit
0..1
<<datatype>>
ChangeType
<<javaclass>> org.eclipse.jgit.diff.DiffEntry.ChangeType
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0..1
parentRelations
0..*
0..1
parent
0..*
childRelations
RevRelation
0..*
Diff
newPath : EString
oldPath : EString
type : ChangeType
0..1
AbstractFileRef
path : EString
source code
PendingElement
binding : EString
linkName : EString
0..*
«fragments»
Target
id : EString
0..*
CompilationUnitModel
0..1
CompilationUnitRef
MoDisco
0..1
0..1
0..1
0..1
NamedElement
(from java)
ASTNode
(from java)
CompilationUnit
(from java)
Model
(from java)

“Demo”

A OCL-like internal Scala DSL for Computing Metrics

- *OCL-like* internal Scala DSL analog to our internal Scala model transformation language [1]
- OCL collection operations mapped to Scala's higher-order fuctions [2]:

1. **L. George, A. Wider, M. Scheidgen:** *Type-Safe Model Transformation Languages as Internal DSLs in Scala*; Theory and Practice of Model Transformations - 5th International Conference, ICMT; 2012
2. **Filip Krikava**: *Enrichting EMF Models with Scala;* Slideshare

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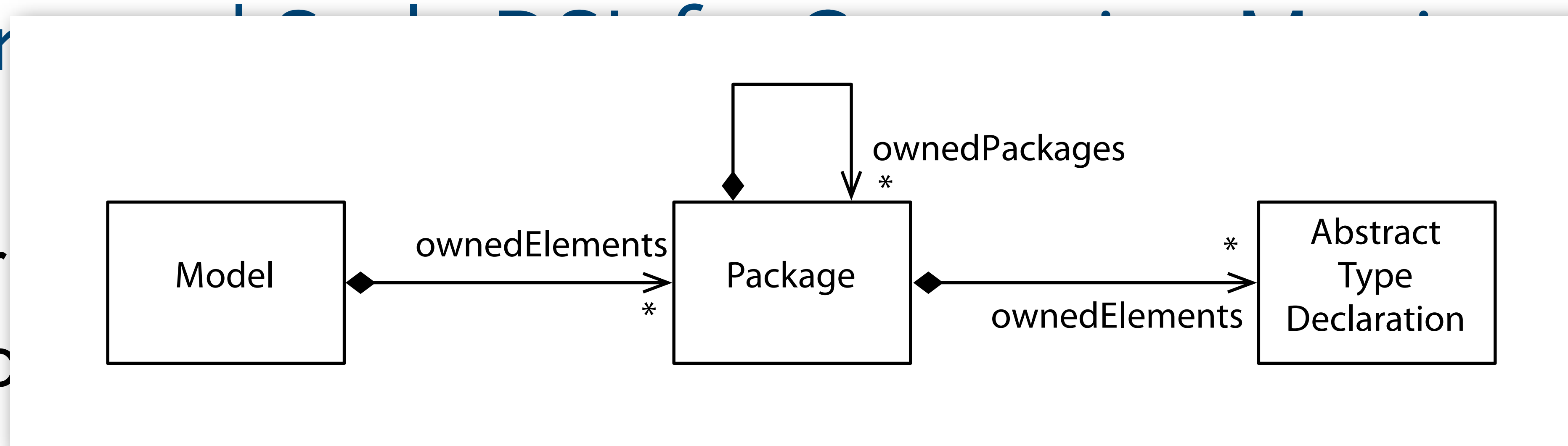

- *OCL-like* inter
  model transfo
- OCL collection operations mapped to Scala's higher-order fuctions [2]:

pure OCL

```
context Model:
    self.ownedElements->collect(p|p.ownedElements)->size
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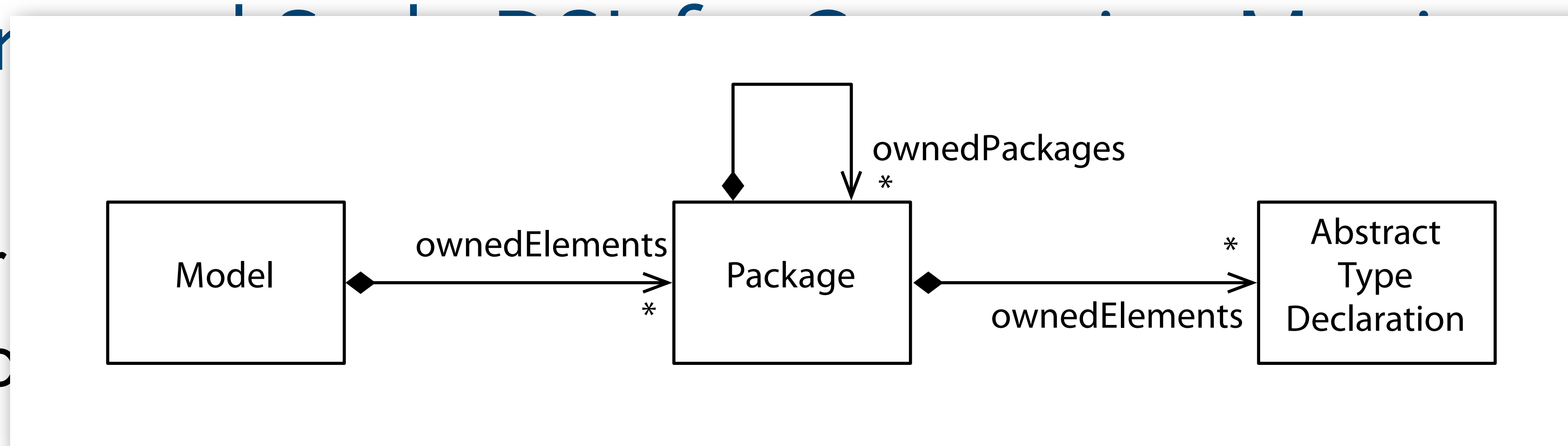

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```

OCL-like expression in Scala

```
def numberOfFirstPackageLevelTypes(self: Model): Int =
    self.getOwnedElements().collect(p=>p.getOwnedElements()).size()
```


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A OCL-like internal Scala DSL for Computing Metrics

- Extending OCL's collection operations:
  - convenience operations
  - closure
  - aggregation
  - execution

```
trait OclCollection[E] extends java.lang.Iterable[E]
{
  def size(): Int
  def first(): E
  def exists(predicate: (E) => Boolean): Boolean
  def forAll(predicate: (E) => Boolean): Boolean
  def select(predicate: (E) => Boolean): OclCollection[E]
  def reject(predicate: (E) => Boolean): OclCollection[E]
  def collect[R](expr: (E) => R): OclCollection[R]

  def selectOfType[T]:OclCollection[T]
  def collectNotNull[R](expr: (E) => R): OclCollection[R]
  def collectAll[R](expr: (E) => OclCollection[R]): OclCollection[R]

  def closure(expr: (E) => OclCollection[E]): OclCollection[E]
```

```scala
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  def collectAll[R](expr: (E) => OclCollection[R]): OclCollection[R]

  def closure(expr: (E) => OclCollection[E]): OclCollection[E]

  def aggregate[R,I](expr: (E) => I, start: () => R, aggr: (R, I) => R): R
  def sum(expr: (E) => Double): Double
  def product(expr: (E) => Double): Double
  def max(expr: (E) => Double): Double
  def min(expr: (E) => Double): Double
  def stats(expr: (E) => Double): Stats

  def run(runnable: (E) => Unit): Unit
}
```

Complex Example: Average Weighted Methods per Class (WMC)

- WMC is the first CK-metric [1]. There different commonly used weights; here we use cyclomatic complexity.

```
def classes(model:Model):OclCollection[ClassDeclaration] =
  model.getOwnedElements()
       .collectClosure(pkg=>pkg.getOwnedPackages())
       .collectAll(pkg=>pkg.getOwnedElements())
       .collectClosure(typeDcl=>
          typeDcl.getBodyDeclarations()
                 .selectOfType[ClassDeclaration])

def WMC(model:Model):Double =
  classes(model).stats(clazz=>
    clazz.getBodyDeclarations()
         .selectOfType[MethodDeclaration]()
         .sum(method=>cyclmaticComplexity(method))).average

def cyclomaticComplexity(method:MethodDeclaration):Int =
  ...
```

1. **S.R. Chidamber, C.F. Kemerer:** *A Metrics Suite for Object Oriented Design*; IEEE Transactions on Software Eng.; Vol.20/Nr.6/1994

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         .sum(method=>cyclma

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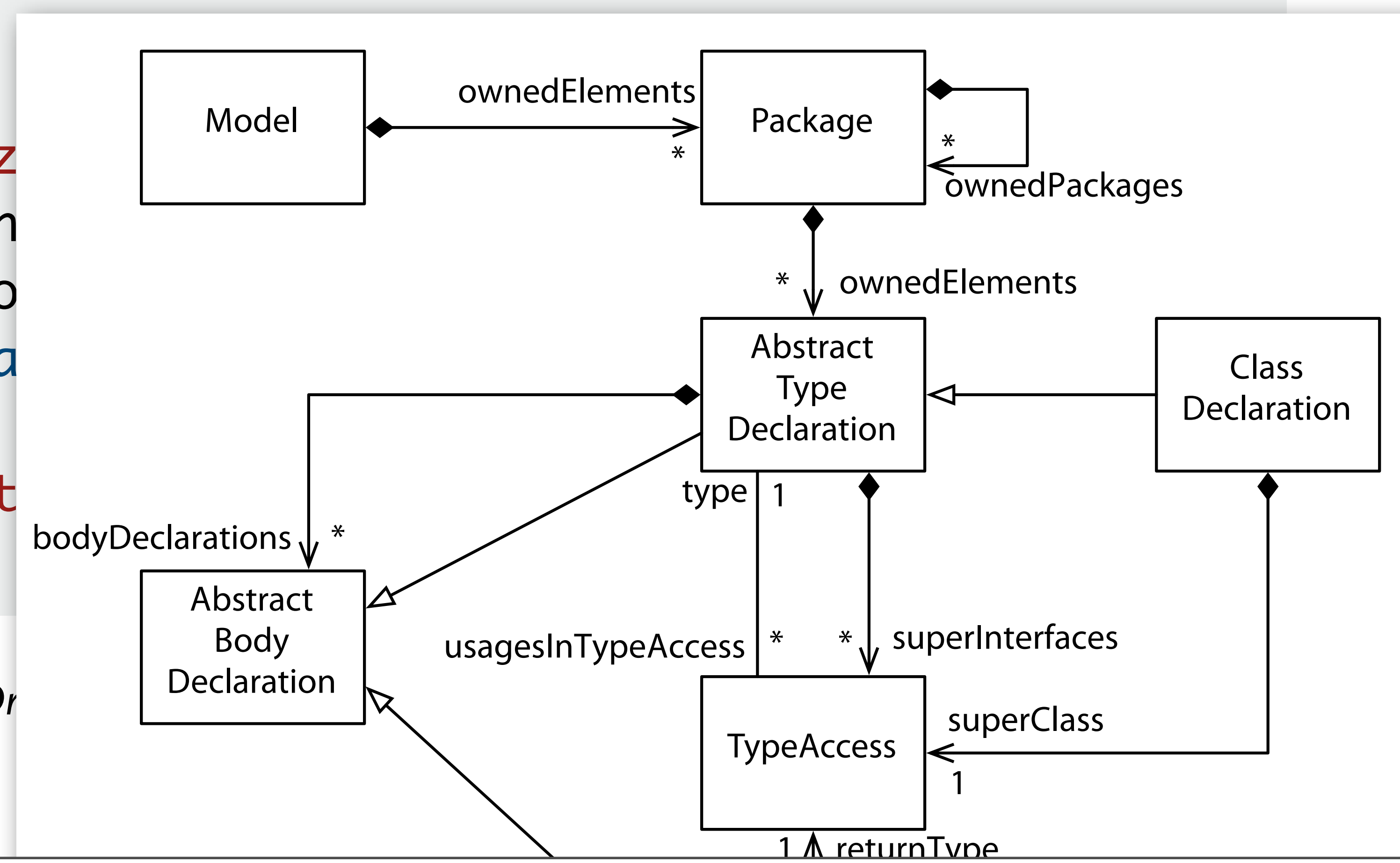
  ...
```



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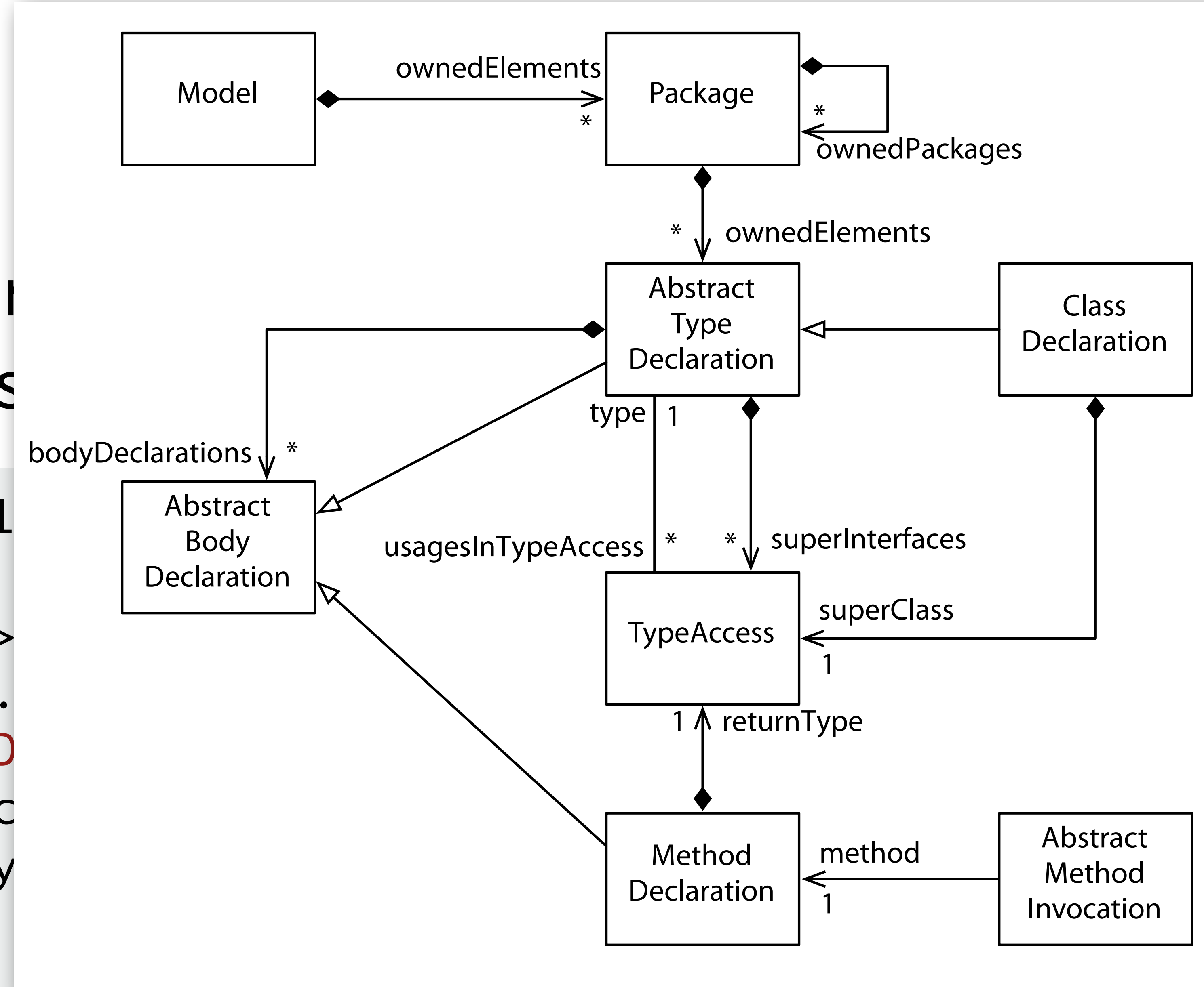


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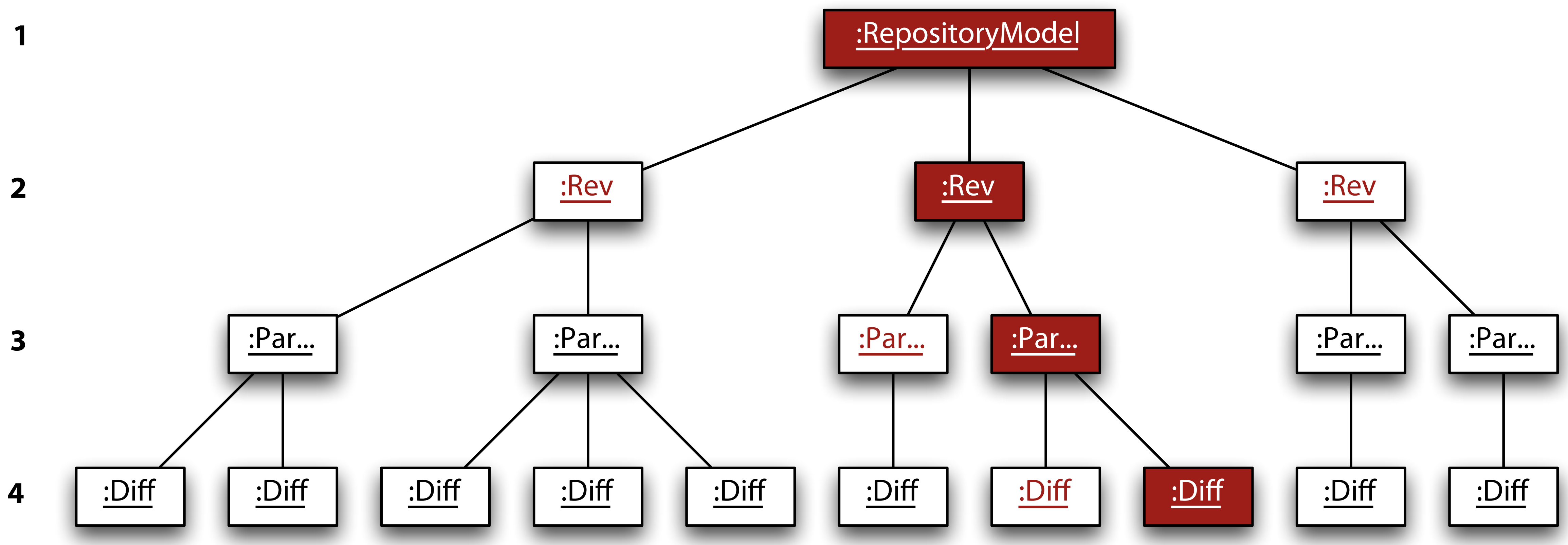
Implementation of the OCL-Collection Operations

- *Just in time* iterator-based implementation rather than straight forward aggregation of result collections.



Future Work, Remaining Problems, and Limitations

Scalability	Heterogeneity	Accessibility	Information Depth
■ very large compilation units ■ incremental snapshot creation ■ batching OCL execution ■ experiments with large scale repository (e.g. *git.eclipse.org*)	■ MoDisco for different programming languages ■ common metrics meta-model (e.g. OMG, KDM) ■ VCS abstraction and support for different VCS	■ relating results to software repository entities ■ persisting and exporting results	■ *diff-models* from comparison of compilation units

- Very large *compilation units* (CU): e.g. a 3 MB, 600 kLOC CU in *org.eclipse.emf*
  - tends to have lots of dependencies → changes often → makes problem even bigger
  - CUs are smallest common denominator between text-based VCS view and syntax-based AST view
  - smaller units require model-comparison or text-to-AST mappings
- Support for different programming languages: either abstraction, parallel meta-models, or mixed approach
  - MoDisco is *extendable*, but only Java support exists; other languages need to be implemented → parallel meta-models
  - A reasonable abstraction for multiple (or all) programming language probably does not exist.
  - A shared abstract meta-model that all language meta-models extends could be an sensible compromise.

Summary

- Overall model-based MSR with *srcrepo* works, but it still needs work.
- 80/20: Uncommonly large CUs are problematic and require complex additions to *srcrepo*. Ignored for now.
- Main goal *heterogeneity* is theoretically plausible, but requires lots of efforts to show practically. Not a matter of *if*, but of *how much*.
- Large experiments are still unfeasible due to lots of small issues rooted in the engineering complexity of the subject matter.