Fast, Faster and Super-Fast Queries

István Ráth
@istvanrath

EMF-IncQuery lead
VIATRA2 committer

Budapest University of Technology and Economics

Edward Willink

Eclipse MMT co-lead
Eclipse OCL lead
Eclipse QVTd lead
Eclipse QVTo committer
OMG OCL 2.4 RTF chair
OMG QVT 1.2 RTF rep
OMG UML 2.5 FTF rep

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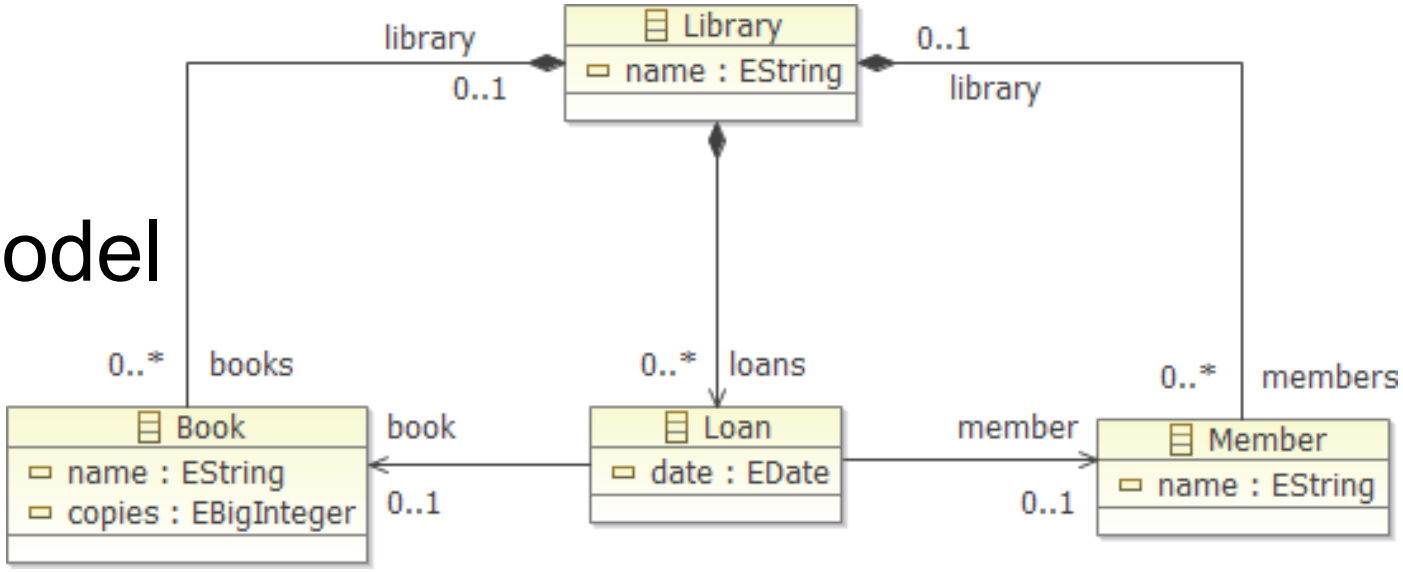
Overview

- Queries and Technologies
- Fast OCL queries
  - OCL to Java code generation
- Faster OCL queries
  - OCL Virtual Machine
- Super-fast queries
  - faster than Java
  - optimized re-evaluation
- Summary

Example Query

- Ecore metamodel
- Ecore model
- Query
  - result derived by computation on model




```
class Library {
 List<Pair<Book, Member>> overdueReport(Date today) {
  List<Pair<Book, Member>> results = new ArrayList<Pair<Book, Member>>();
  for (Loan loan : library.getLoans()) {
   if (loan.getDate() < today) {
    results.add(new Pair<Book, Member>(loan.getBook(), loan.getMember());
   }
  }
  return results;
 }
}
```

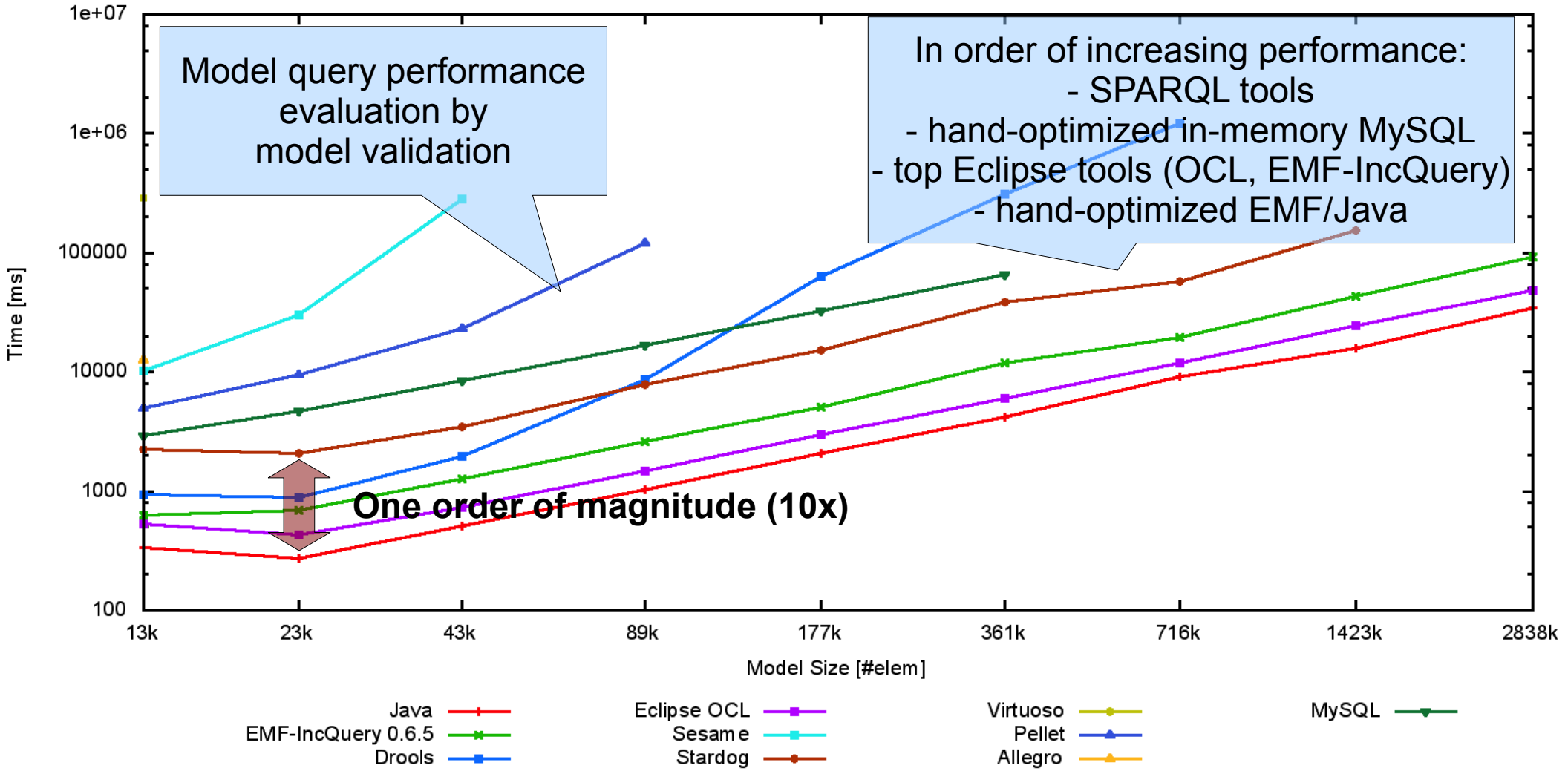
- EMF Java to produce overdue Book+Member report

Query Technologies

Increased abstraction/portability

Technology	Data model	Query language	Expressive power	Execution
SQL	RDBMS	SQL	Tuple relational calculus	Compiler
XML/XPath	XML documents	Xpath expression language	Tree path expressions	Interpreter
SPARQL	RDF	Graph pattern based logical queries (SPARQL)	Tuple relational calculus	Interpreter, compiler
OCL (active)	EMF,...	OCL Expression	Powerful functional language	Interpreter, compiler
EMF Query (mature)	EMF	SQL-like	Simple queries (subset of SQL)	Interpreter
EMF Query2 (incubation)	EMF	SQL-like	Simple queries (subset of SQL)	Interpreter with index
EMF-IncQuery (incubation)	EMF,...	Graph pattern based logical queries (IQPL)	Tuple relational calculus + extras (comparable to OCL)	Interpreter, compiler
Xtend (active)	EMF	Xbase Expression	Extended Java	Compiler

Batch Evaluation Time vs Model Size



Complete OCL

```
context Library
def: overdueReport(today : ecore::EDate) : Bag(Tuple(book : Book, member : Member)) =
    loans->select(date < today)->collect(loan | Tuple{book = loan.book, member = loan.member})
```

- Complementary document
  - extra operations/properties/invariants
  - existing meta-model unaware of the complements
- Pre-Indigo: no OCL editing support
  - Java API for many years
  - only useable in custom applications
- Indigo: Xtext editor
- Juno: Load Complete OCL Resource...
  - Xtext/Ecore/UML can be complemented

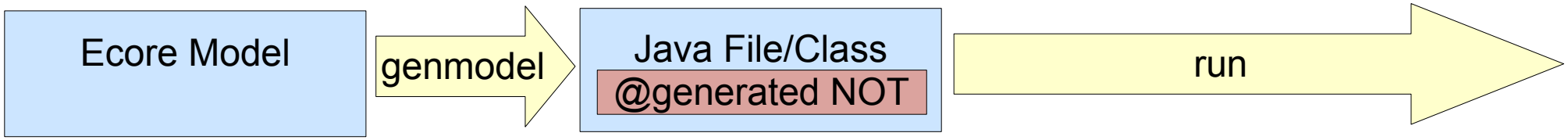
Embedded OCL

```
class OverdueTuple {
    property book : Book;
    property member : Member;
}
class Library {
    operation overdueReport(today : ecore::EDate) : OverdueTuple[*] { !unique } {
        body: loans->select(date < today)->collect(loan : Loan | OverdueTuple{book = loan.book, member = loan.member});
    }
    attribute name : String;
    property loans : Loan[*] { composes };
}
```

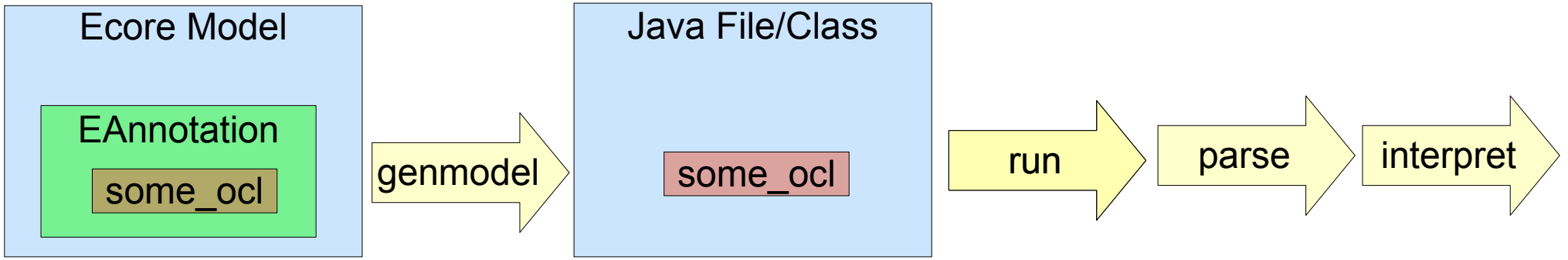
- Pre-Helios: no OCL editing support
  - manual XML editing of CDATA and EAnnotations
- Helios: Xtext OCLinEcore editor
  - automates EMF Delegate EAnnotations entry
  - OCL source embedded in EMF's Java
    - automatically executed by OCL interpreter
- Juno: OCL to Java code generator
  - automatically executed by EMF genmodel

Fast OCL execution

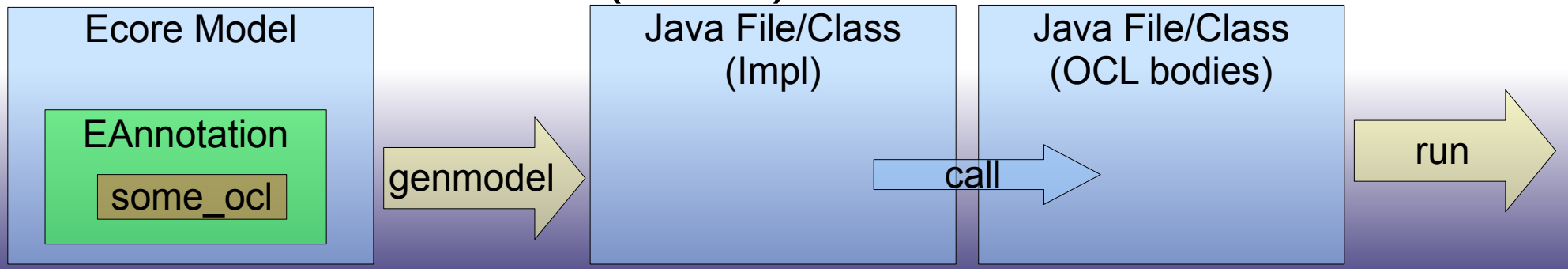
@Generated NOT manual Java (pre-Helios)



EMF Delegates support EAnnotations (Helios)

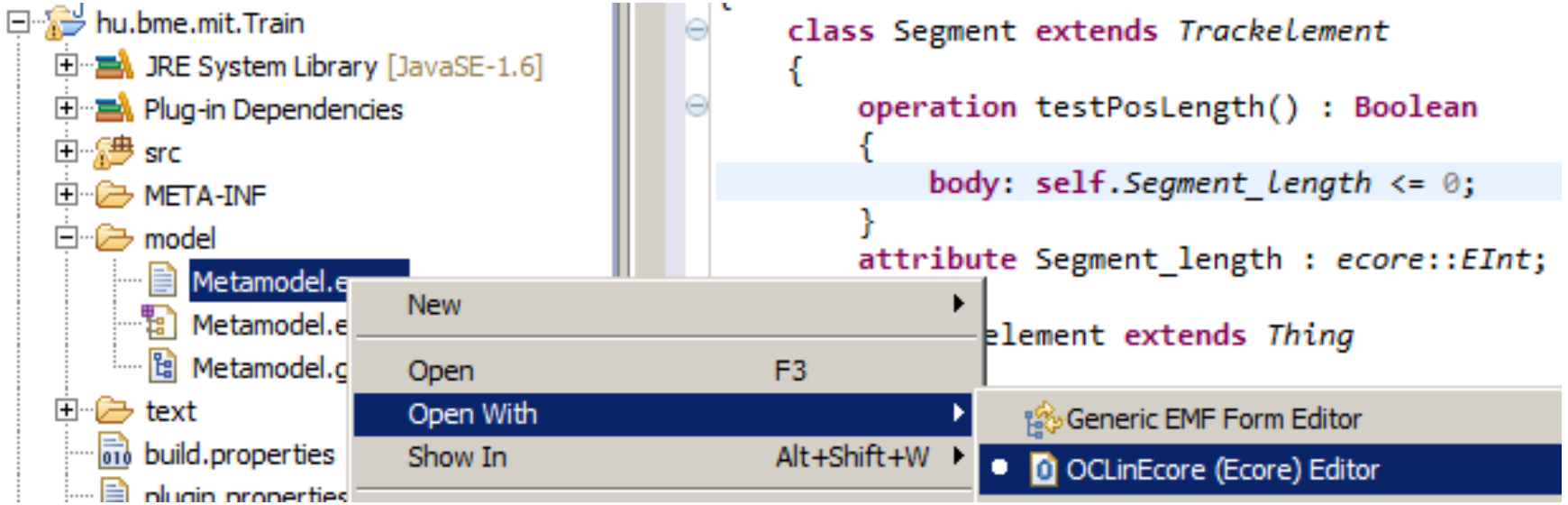


Direct OCL 2 Java (Juno)

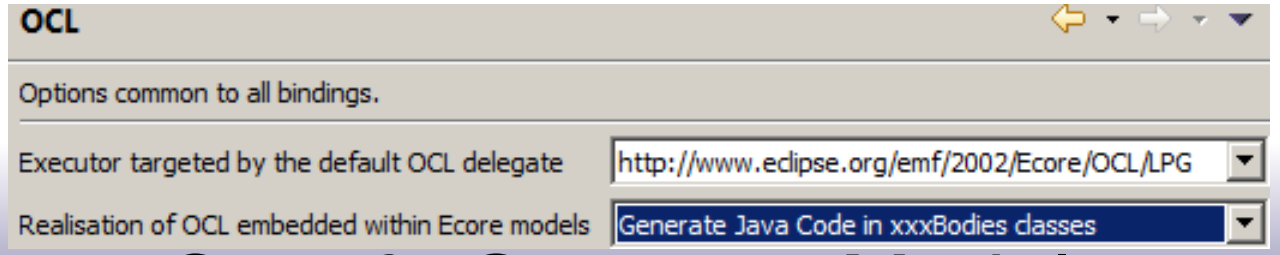


Useable OCL

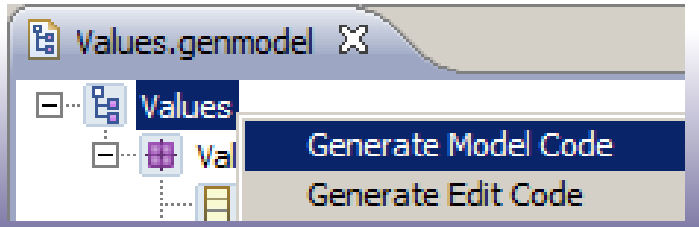
- Step 1, Add OCL to Ecore



- Step 2, optionally enable Code Generation
  - Window->Preferences->OCL



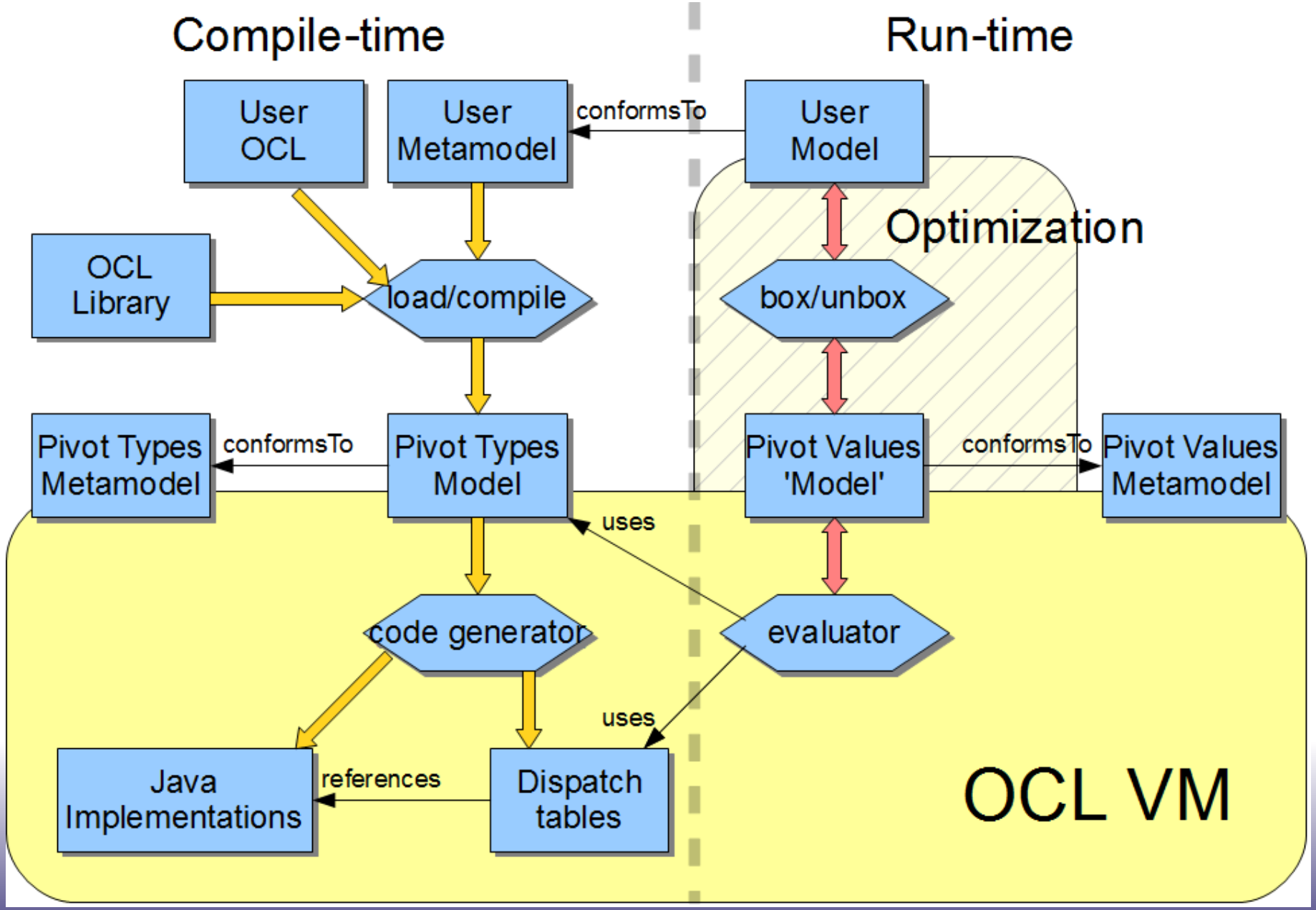
- Step 3, Generate Models



Fast OCL Execution Support

- Fast Control
  - Acceleo templates tree-walk at compile-time
- Fast Values with OCL semantics
    - 1 is always equal to 1.0 (Java: only sometimes equal)
    - unlimited integers (Java: unchecked 32/64 bit wraparound)
  - Polymorphic Values
- Fast Operations and Properties
  - Polymorphic feature implementation API
- Fast Reflection, Metamodel access
  - auto-generated dispatch table view of metamodel

The Eclipse OCL VM



Is the OCL VM Faster?

- Fast Control, Values, Operations, Reflection
- Juno Code Generator performance
  - no run-time parsing costs - good
  - subsequent speed similar - really disappointing
- Investigation
  - eGet("XXX") costly
    - code generate as getXXX saves 30%!
  - fully polymorphic values are very costly
    - every collection is copied
    - every collection element is wrapped by a 'box' object

Smart Code Generation => Faster

- Kepler M3 is 3 to 29 times faster than Juno
  - Partial value polymorphism
    - EMF collections used directly
    - only Integer, Real and EClass objects wrapped/boxed
  - static analysis eliminates `instanceof` costs
    - redundant polymorphic dispatch eliminated
- Still To Do
    - deeper analysis of invalid/null
    - operation inlining, CSE, ...

Faster, Extensible OCL Evaluation

- OCL evaluation is just a tree walk over the AST
  - interpreter visits tree nodes directly at run time
  - compiler pre-visits tree nodes at compile time
- Extended languages add extra AST classes
  - extra visitor methods
  - same evaluation process
  - same debugging requirements
- OMG extended languages
  - QVTc, QVTo, QVTr, MOFM2T (Acceleo)

Real systems

- Simple systems - full evaluate once
  - just need efficient evaluation
- Real systems
  - evaluate [small-change re-evaluate]*
- Naive Java full re-evaluation costly
    - e.g. Xtext substantially reconstructs intermediates
    - reliable hand-coded incremental update error-prone
- Intelligent re-evaluation is selective
    - "Only recalculate what is necessary, reuse the rest"

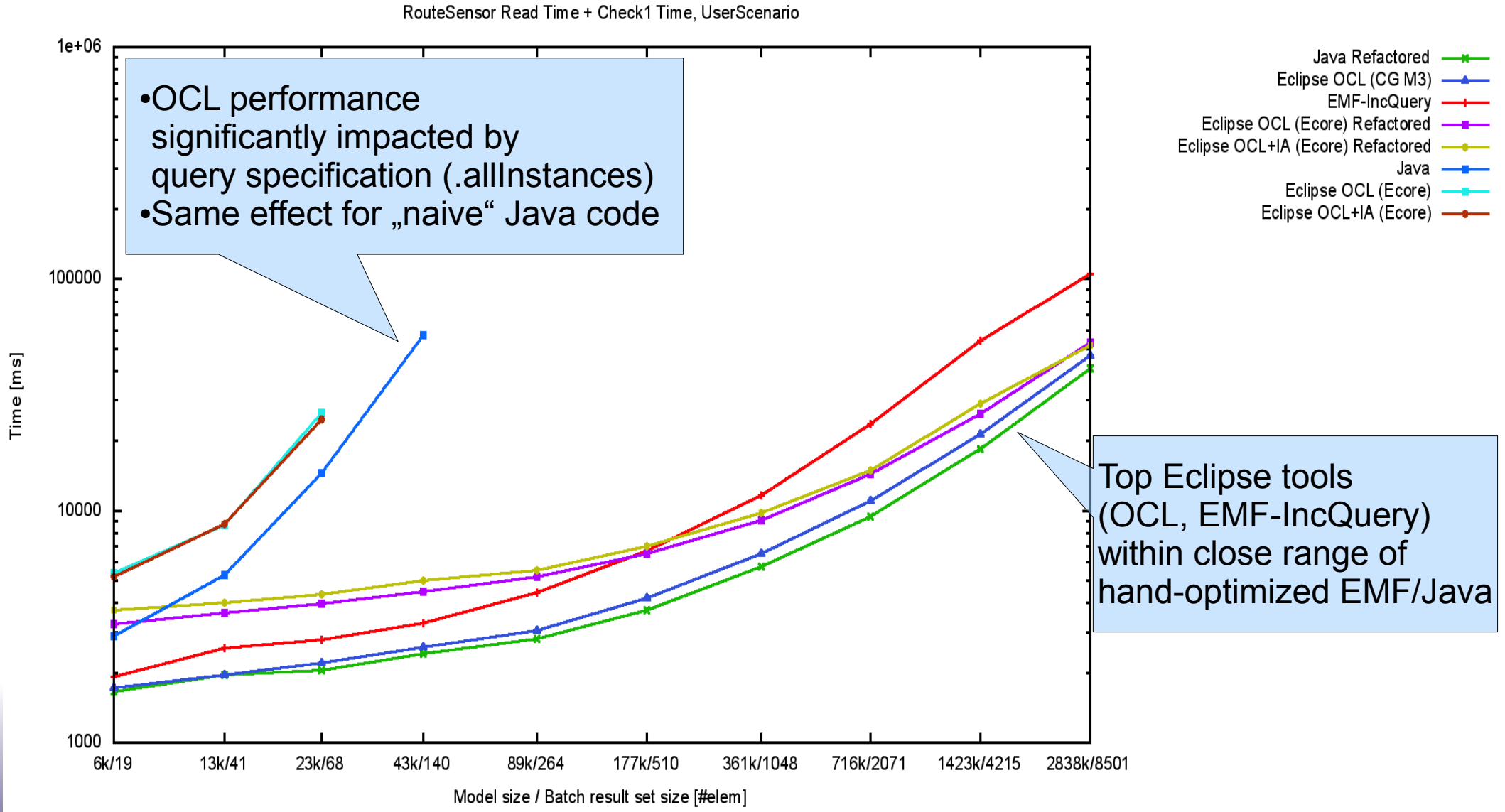
Benchmarking

- Goal: to assess query performance of EMF-based tools
- Methodology
  - Use small (<1000 EObjects), medium (10-100k EObjects) and very large instance models (up to 2.8M EObjects)
  - Queries of varying complexity
- Benchmarking loop (measure memory usage throughout)
  - Load model (measure model initialization time)
  - Evaluate queries (measure evaluation time)
  - Modify model (measure modification time)
  - Re-evaluate queries (measure re-evaluation time)

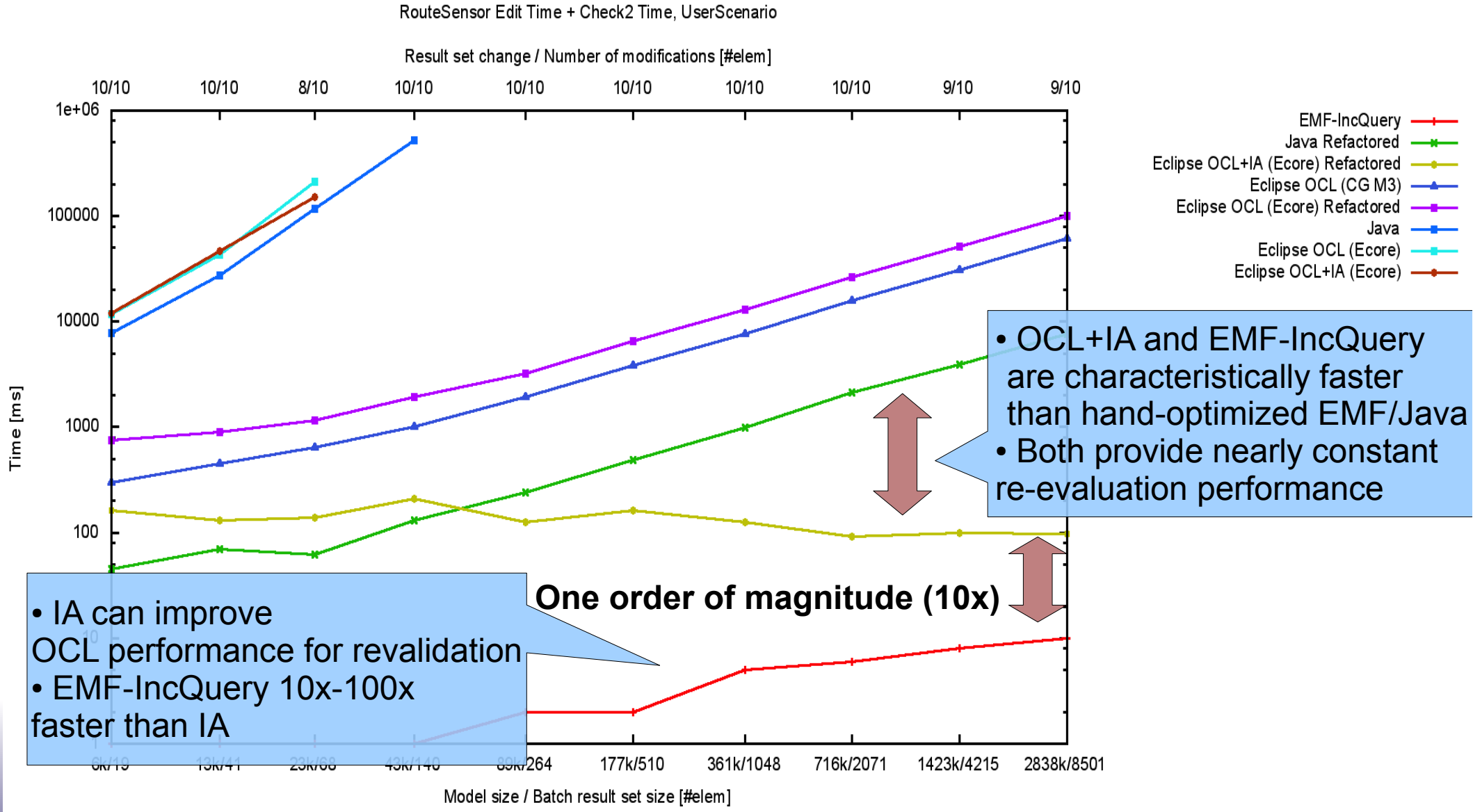
Batch validation

(Incremental) revalidation

Batch Validation Reprise



Surprise (?): Re-validation



The reason: the power of declarative approaches

- Java: imperative expressions with side effects
  - Code difficult/impossible to analyze
- Declarative languages: side-effect free expressions
  - programs can be analyzed to optimize change processing
  - supports efficient re-evaluation: only re-evaluate those areas affected by changed input
- Approaches
  - OCL Impact Analyzer
  - EMF-IncQuery

EMF-IncQuery: Pattern queries

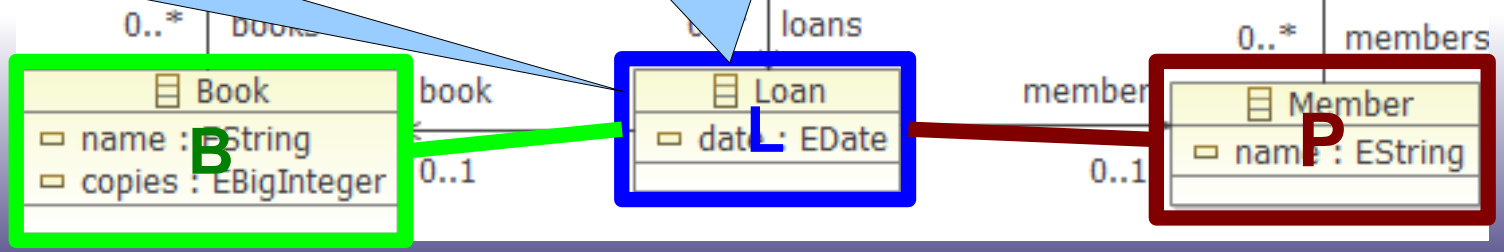
- OCL expressions: Model-based evaluations
  - Constraint - returns true/false
  - Query - returns one or more values/objects
- IncQuery Patterns: Additional Abstraction
  - Query - returns a tuple of matching objects
  - (Constraint – an annotated query)
  - objects in source model
    - constrained by instance type
    - constrained by inter-relationships
    - constrained by arbitrary subqueries
      - attribute constraints as restricted/side-effect free Xbase expressions

Pattern example

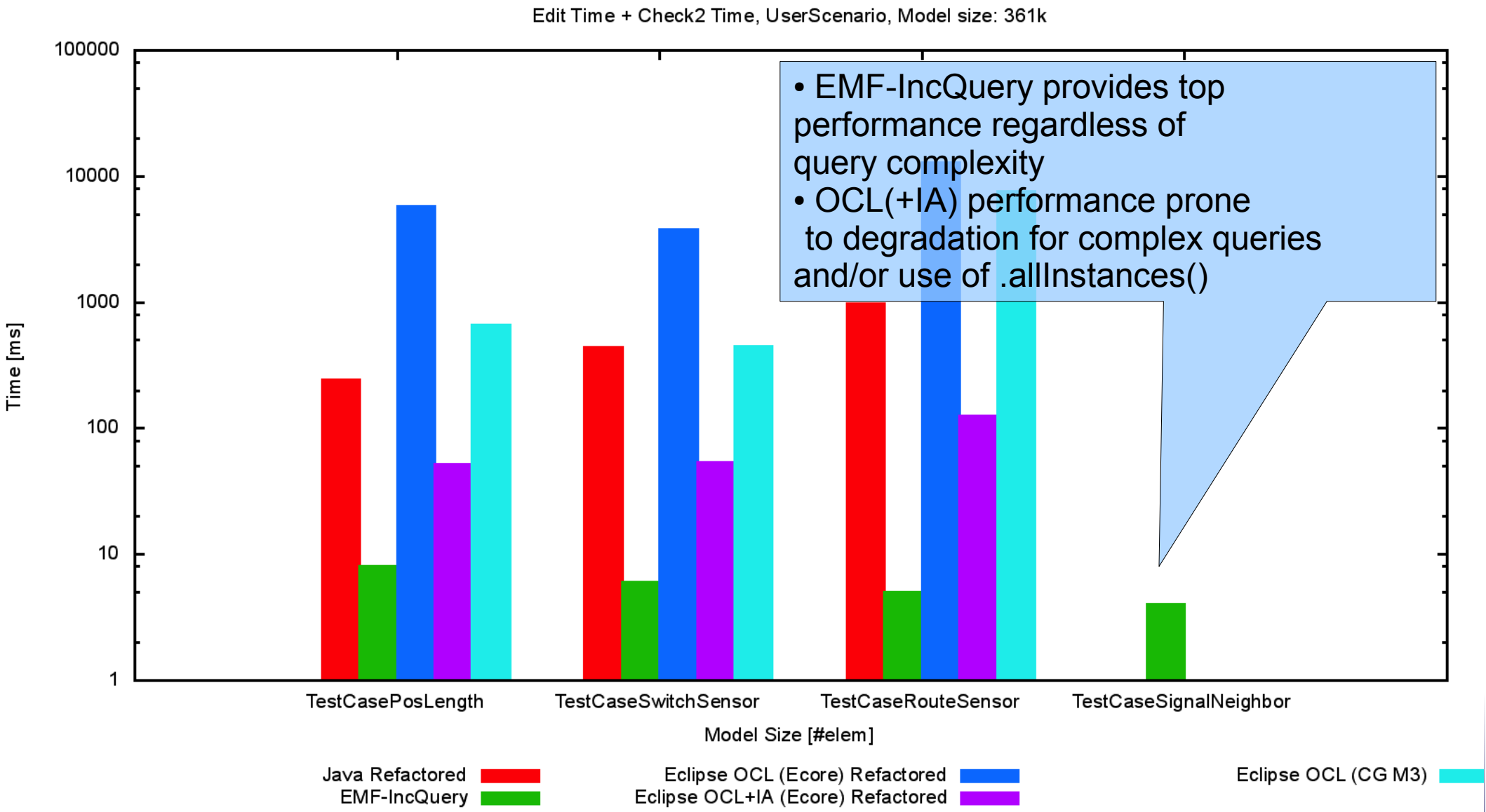
```
pattern OverdueBooks(P: Member, B:Book, Today: Date)
{
    Loan(L); // declaration optional due to type inference
    Loan.book(L,B);
    Loan.member(L,P);
    Loan.date(L,D);
    check(Today.after(D))
}
```

Incremental example
- a book is renewed
  - one due date changes
  - one OverdueBooks match changes
  - << full-re-evaluation

Incremental example 2
- today becomes tomorrow
  - all comparisons previously returning true re-evaluate
  - some OverdueBooks matches change
  - < full-revaluation



Comparing rule "difficulty"



EMF-IncQuery

- Coming very soon to Eclipse Modeling, get it from the Marketplace today
- Features available today
  - Fully featured Xtext2-based developer tools
  - Integration options
    - Generic/generated API: both query results and incremental deltas
    - Query-based derived EReferences/EAttributes with notification support
    - Databinding support
  - Interactive Query Explorer to provide live views of models, works with any EMF-based tool
- Near future
  - Zest visualization support
  - Full UML support (Dynamic EMF)

Super-fast queries

- Today in Juno
  - OCL+IA can reduce re-evaluation times
  - EMF-IncQuery
    - Provides top performance regardless of model size and query complexity (much faster than OCL+IA and handwritten Java)
    - At the cost of somewhat increased memory consumption
- Future
  - Synergies between EMF-IncQuery and OCL(+IA)
  - Common framework for query-based features

Super-fast queries

- Today in Juno
  - OCL+IA can reduce re-evaluation times
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To see EMF-IncQuery in live action doing realtime gesture recognition, check out Jonas Helming's Jnect Session on Thursday:

Jnect – Get Your Eclipse Moving
(Thursday 2.30PM-3PM, Theater)

Summary

- Fast
  - direct OCL to Java code generation
- Faster
  - efficient OCL Virtual Machine dispatch tables
  - ongoing optimizations
- Super-fast
  - declarative (re-)evaluation can be optimized with EMF-IncQuery and OCL+IA
  - **much faster than (naive/typical) Java!**

Unused slides

Xcore and friends / OCL

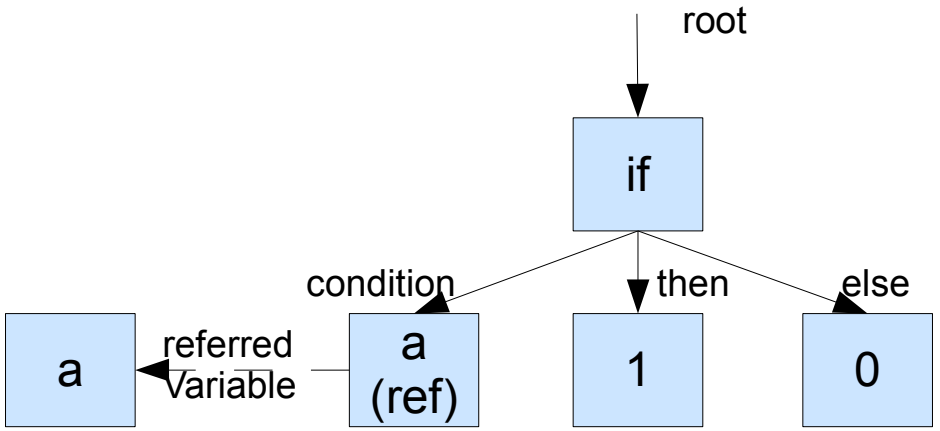
- If all you want is Java
  - use Xcore/Xbase not OCL
- OCL is a Specification language -
  - platform neutral
- Sharper syntax
  - much of it adopted by Xbase
- Declarative
  - side effect free, no assignment
- Foundation for MOFM2T(Acceleo), QVT, ...

OCL Code Generator

- Acceleo templates
  - flexible, extensible
  - eliminates run-time parsing costs
- Run-time speed not significantly faster
  - polymorphic, accurate, UML-aligned
- Juno 2012, pivot-based code generator
  - Acceleo OCL to Java templates
  - eliminates run-time compilation
    - not significantly faster

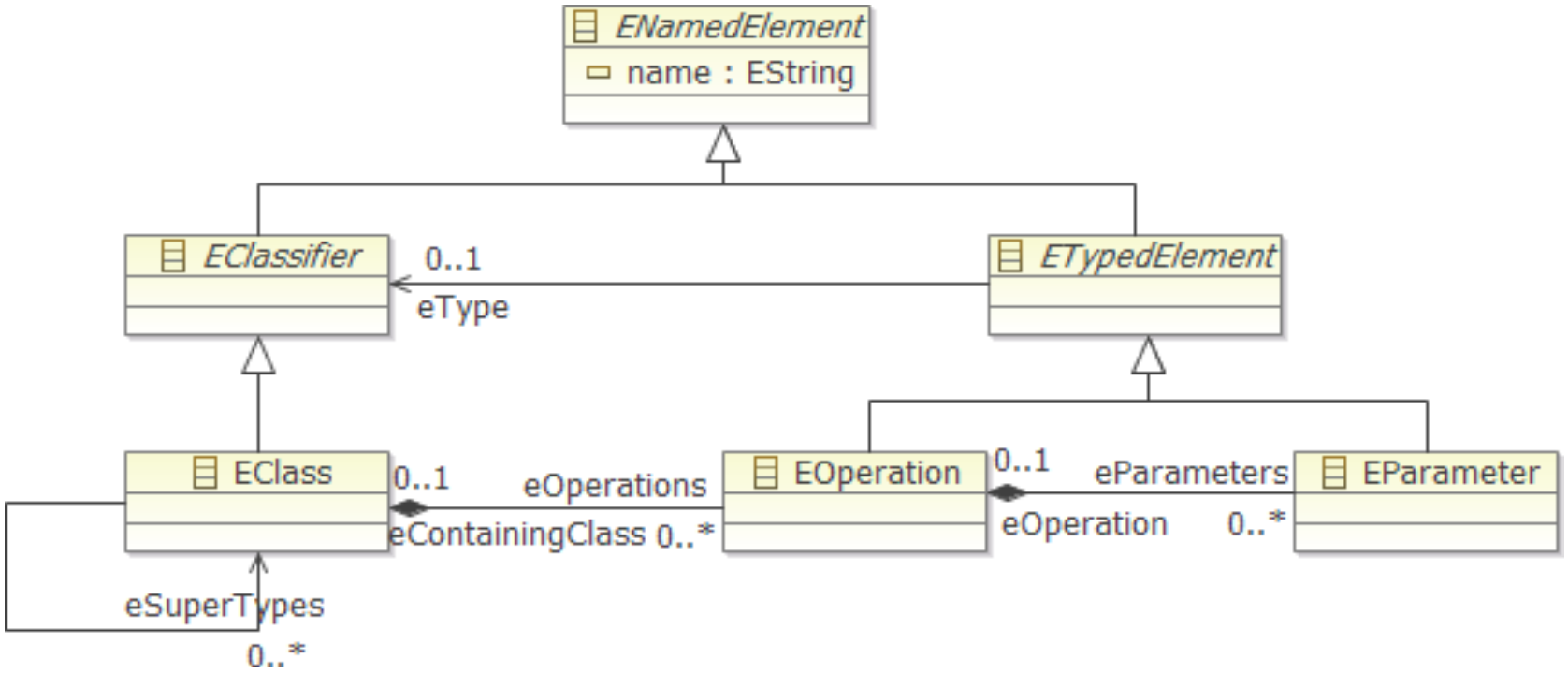
OCL Evaluation Principles

- AST Tree walk
  - root to if to ...
- AST node per usage
  - IfExp
  - VariableExp
  - IntegerLiteralExp
- Extensible
  - Polymorphic AST nodes
  - auto-generated Visitor (faster than Ecore Switch)



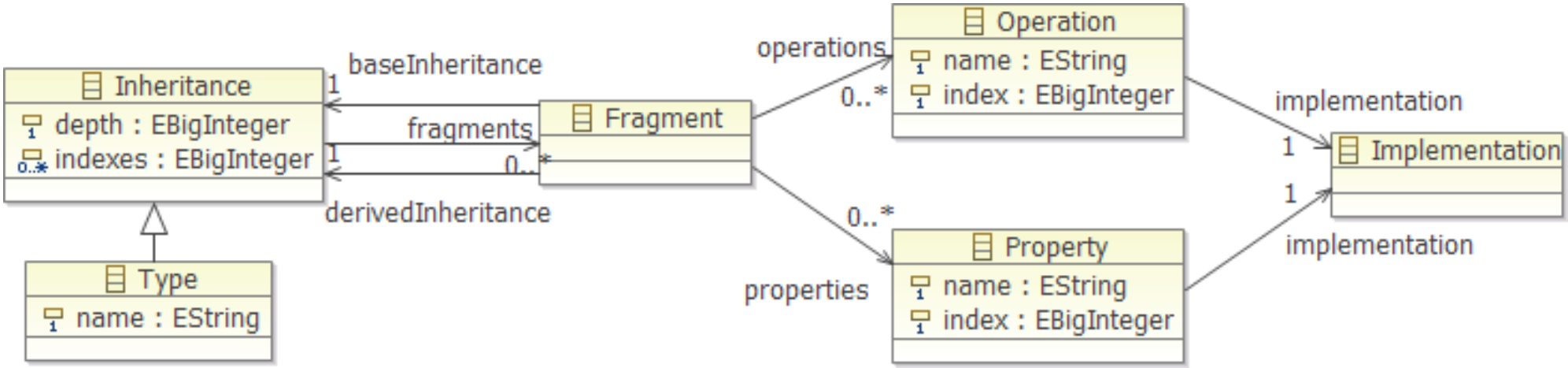

```
if a then 1 else 0 endif
```

'Ecore' Operation Call : a.b(c,d)



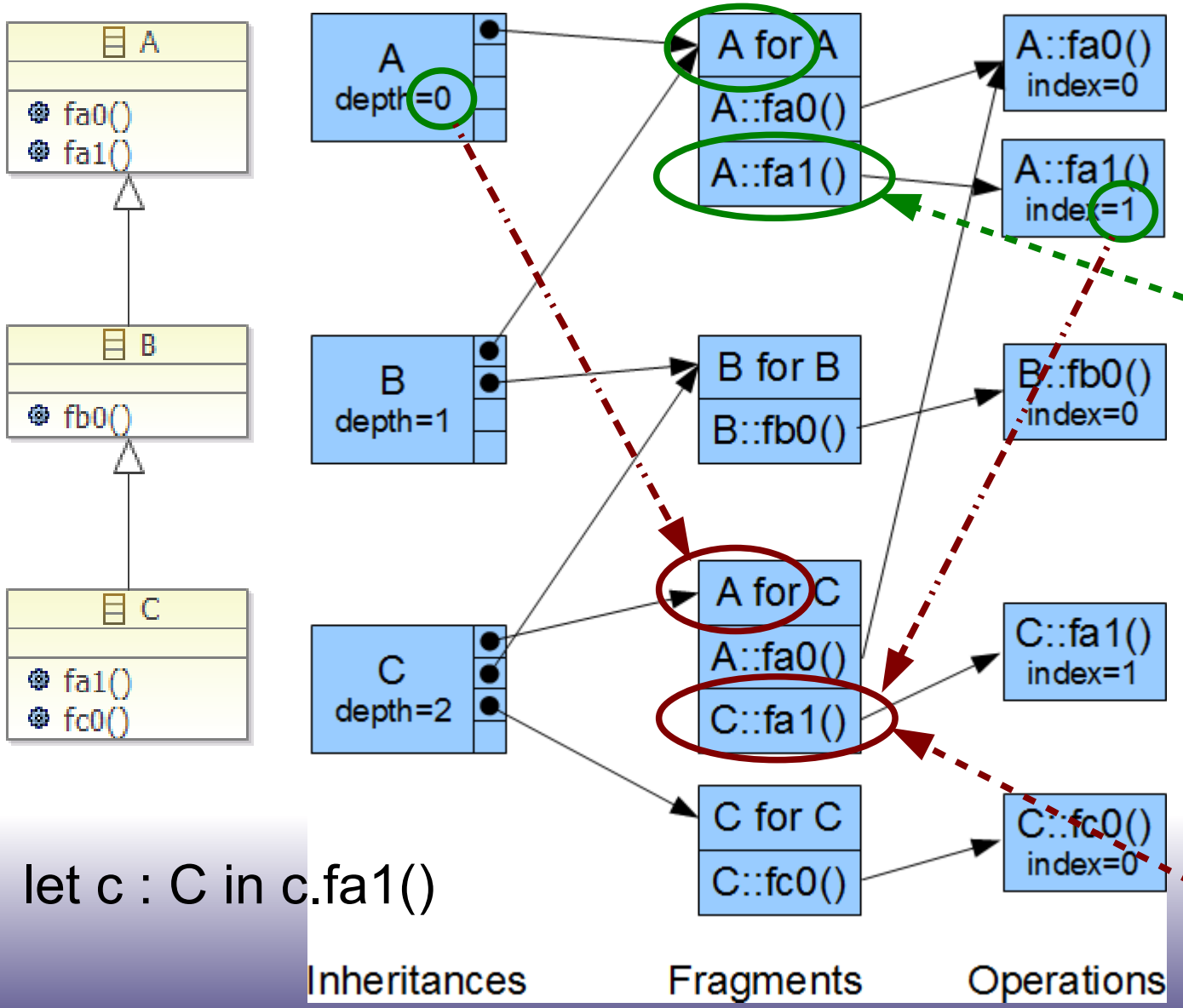
- Tree search over type and supertypes --- a
  - Linear search for operation name --- b
    - Linear search to match argument types --- (c,d)
      - Tree search for conformant type/supertype --- c then d
- Select best unique match

'OCL VM' Operation Call



- Fragment provides derived view of base
  - may have overloaded entries
- Linear search of fragments at required depth
  - Direct index to operation

Example OCL VM dispatch



- Problem
  - fa1() for a C
- Compile-time
  - A::fa1
  - depth 0, index 1
- Run-time
  - C
  - A is depth 0
    - A for C
  - A::fa1 is index 1
    - C::fa1

let c : C in c.fa1()

OCL Virtual Machine => Faster

- Non-polymorphic values bad
  [org.eclipse.ocl.ecore since at least Europa]
  - Boolean, String, Integer ...
  - difficult/impossible to have precise OCL semantics
- Fully polymorphic values bad
  [org.eclipse.ocl.examples.pivot since Indigo]
  - BooleanValue, StringValue, IntegerValue ...
  - too many boxing/wrapping objects
- Partially polymorphic values also bad
  - Boolean, String but IntegerValue ...
  - too many **`instanceof`** tests

Simple Interpreted OCL VM

- Program is an Abstract Syntax Graph (AST)
  - VariableExp
    - references variable to read as a value
  - PropertyCallExp
    - references object and property to read as a value
  - OperationCallExp
    - references operation to apply to some values
- Run-time Interpretation
  - tree-walking evaluation visitor
- Extensible with new AST node classes

Code Generated OCL VM

- Program is an Abstract Syntax Graph (AST)
- Compile-Time Code Generation
  - tree-walking code generating visitor
- Run-time Execution
  - direct Java, direct model accesses
- Extensible with new AST node classes
- Optimisable
  - direct model access getXX() rather than eGet('XX')
  - inlining of non-polymorphic (final) operations

(Imperative) OCL VM for QVT

- Simple OCL VM
  - AST walker
  - QVT richer AST
- Code generated VM
  - dispatch tables
  - flattened code
  - inlined operations
- Debugging tools