
# Metaprogramming and Reflection
## Refactoring

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# Topics Covered

- Overview
- Introduction
- Open implementations
- OMG meta object facility
- CLOS metaobject protocol
- Smalltalk/Squeak
- Behavioral reflection
- Refactoring browser
- AspectS and ContextS
- Traits and mirrors
- Metacircular interpreters

# Outline

- Refactoring: Basics
- Refactoring in Squeak: Browser + Tools
- Refactoring Engine: Implementation
- Discussion: Reflection?

# What is Refactoring?

- The process of *changing a software system* in such a way that it *does not alter the external behaviour* of the code, yet *improves its internal structure*.

  – Fowler, et al., Refactoring, 1999.


# Typical Refactorings

| Class | Method | Attribute |
|---|---|---|
| add (sub)class to hierarchy | add method to class | add variable to class |
| rename class | rename method | rename variable |
| remove class | remove method | remove variable |
| | push method down | push variable down |
| | push method up | pull variable up |
| | add parameter to method | create accessors |
| | move method to component | abstract variable |
| | extract code in new method | |

# Why Refactor?

***"Grow, don't build software"***

– Fred Brooks

- The reality:
  - Extremely difficult to get the design "right" the first time
  - Hard to fully understand the problem domain
  - Hard to understand user requirements, even if the user does!
  - Hard to know how the system will evolve in five years
  - Original design is often inadequate
  - System becomes brittle over time, and more difficult to change

- Refactoring helps you to
  - Manipulate code in a safe environment (behavior preserving)
  - Recreate a situation where evolution is possible
  - Understand existing code

# Rename Method — manual steps

- Do it yourself approach:
  - Check that no method with the new name already exists in any subclass or superclass.
  - Browse all the implementers (method definitions)
  - Browse all the senders (method invocations)
  - Edit and rename all implementers
  - Edit and rename all senders
  - Remove all implementers
  - Test

- Automated refactoring is better !

# Rename Method

- Rename Method (method, new name)
- Preconditions
  - No method with the new name already exists in any subclass or superclass.
  - No methods with same signature as method outside the inheritance hierarchy of method
- PostConditions
  - method has new name
  - relevant methods in the inheritance hierarchy have new name
  - invocations of changed method are updated to new name
- Other Considerations
  - Typed/Dynamically Typed Languages => Scope of the renaming

# Refactoring and Metaprograming

- Automated Refactoring is metaprograming
  - We use a program to edit programs
- Does not need to use Reflection
  - Pure source-to-source transformation (e.g. Java)
- Uses reflective facilities in Smalltalk
  - But… let's discuss that at the end

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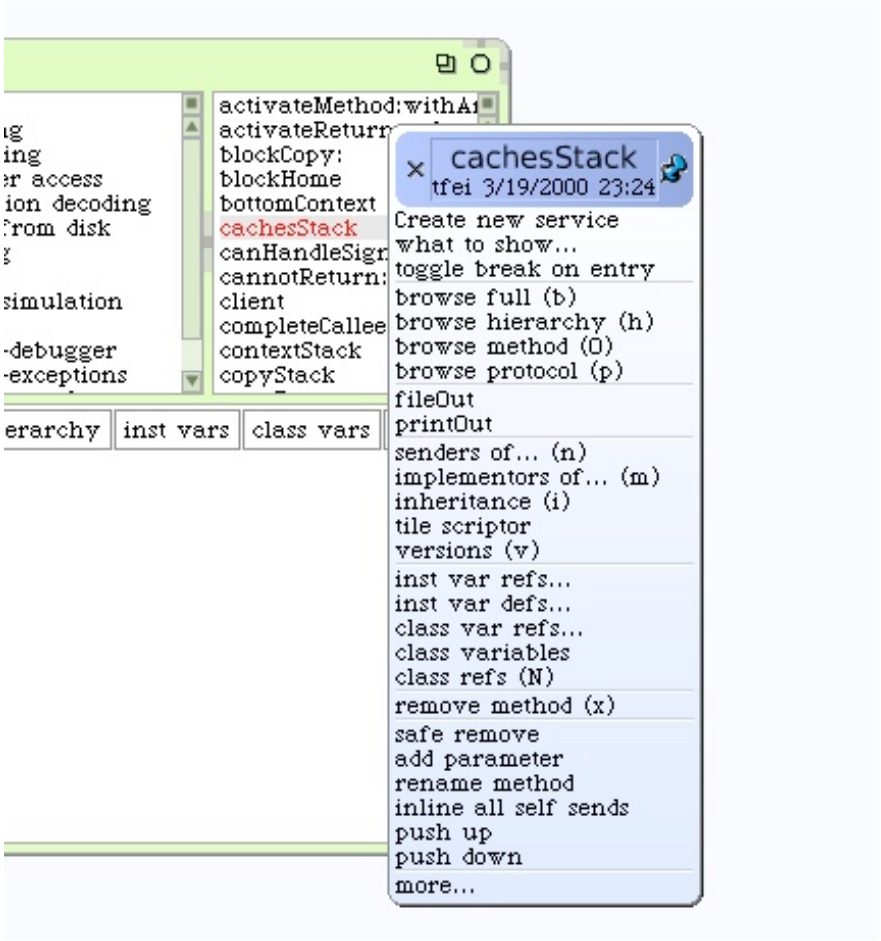
# Refactoring in Squeak

- No support in standard IDE
  - Example: Try to rename a method
- Refactoring Browser
  - First Refactoring Browser (for any language)
  - Now over 10 years old
- Installation
  - Get Squeak 3.9 (older version for 3.8, too)
  - Install Package AST
  - Install Package Refactoring Engine

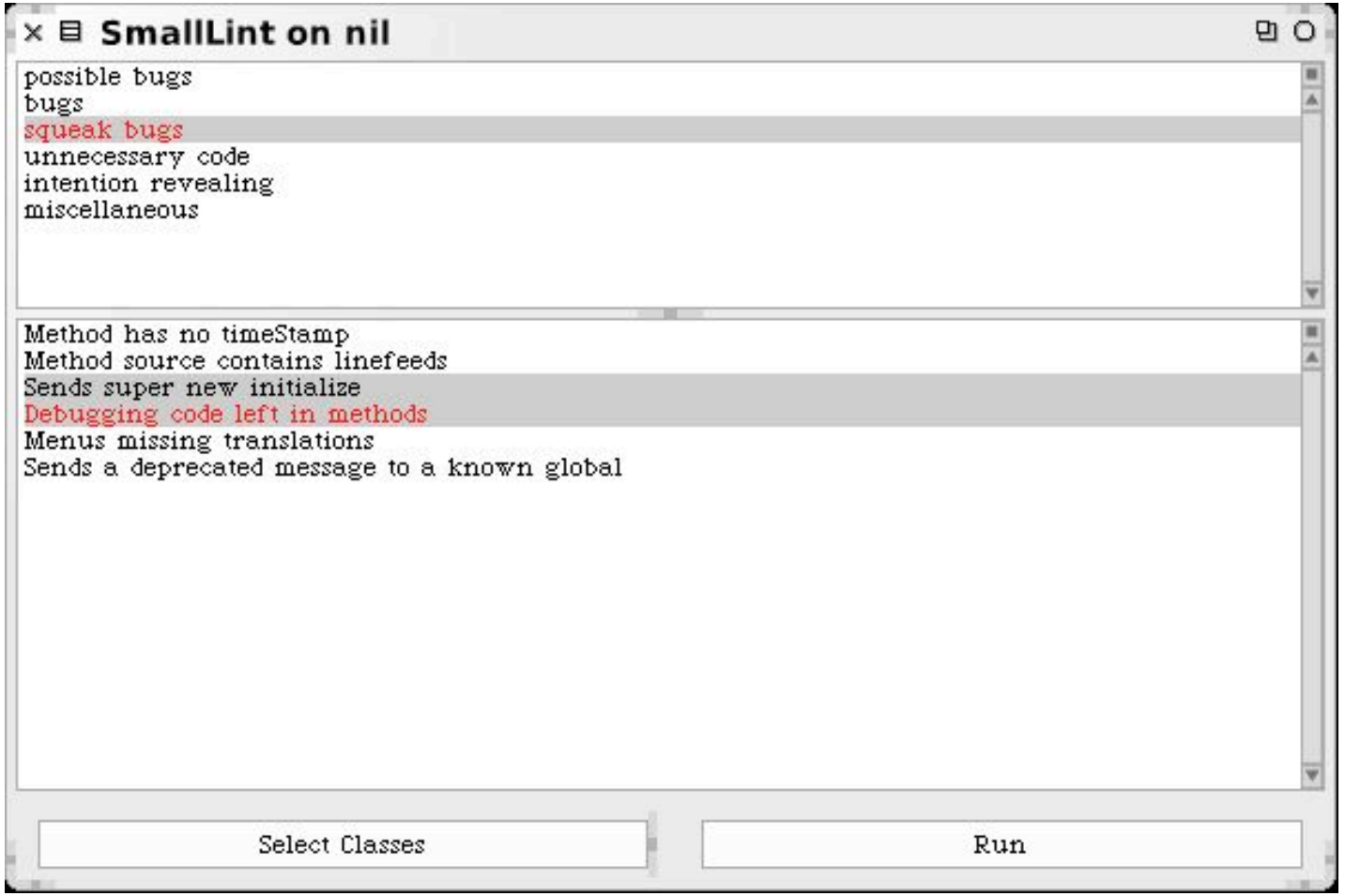
# Refactoring Browser

- Browser with menus for e.g
  - rename
  - Push up/down
  - Inlining
  - Add parameter
  - Extraction



# SmallLint

- Checks for common mistakes



# SmallLint Checks

- Possible Bugs
  - Variable read before written
  - Defines #= but not #hash
  - Modifies Collection while iterating over it
- Bugs
  - Uses True/False instead of true/false
  - Variable used but not defined
- Squeak Bugs
- Unnecessary Code
- Intention Revealing

# SmallLint

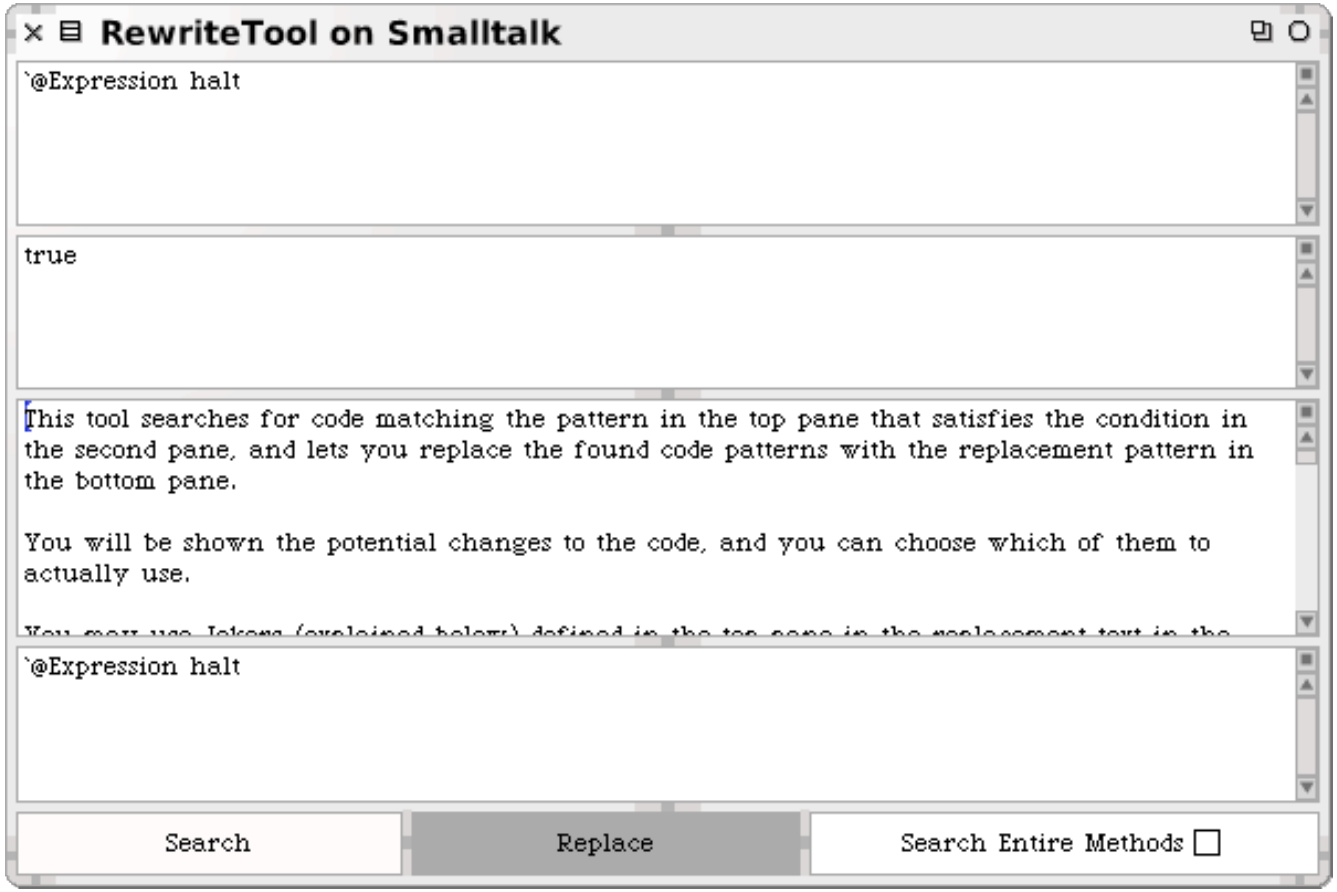
- Very useful!
- Especially valuable for beginners

- Has been integrated with SUnit
  - Call SmallLint automatically as a test

- Tag methods where SmallLint is wrong
  - Uses Squeak 3.9 Method Pragmas

# RewriteTool

- Pattern driven automatic editor



# RewriteTool

- Access to full power of Refactoring Engine
- Custom refactorings:
  - generic rewrites that the RB does not currently provide
  - bulk transformations: your project needs to change a project-specific pattern to a new form
  - changing layers: e.g. build a new DB layer, find and change 17,000 references to old layer
  - migrations: e.g. between Smalltalk dialects
- Powerful but not trivial to use
- Examples: Later

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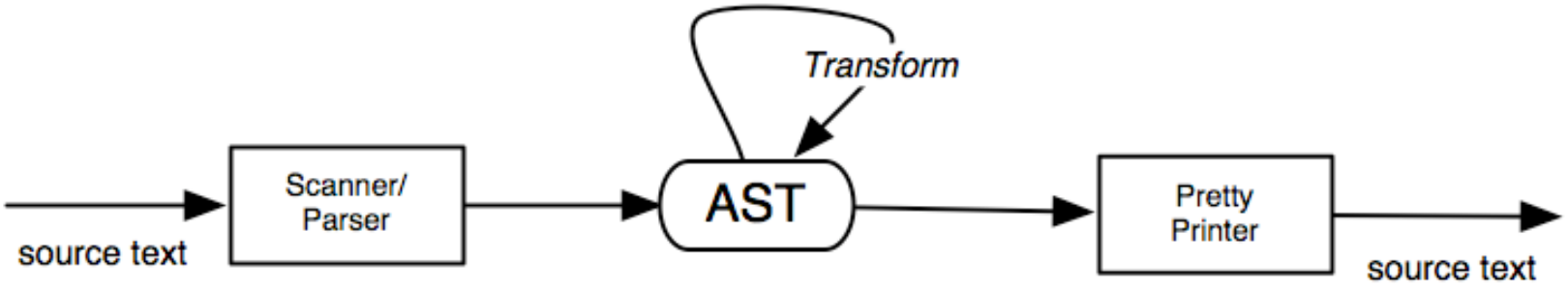
[Main Source] Don Roberts, John Brant, and Ralph Johnson. A Refactoring Tool for Smalltalk. *Theory and Practice of Object Systems*, vol. 3, issue 4

# Implementation Overview

- Goal: Transformation on the Source
- Idea: Transform into a higher level tree representation



# The RB Abstract Syntax Tree

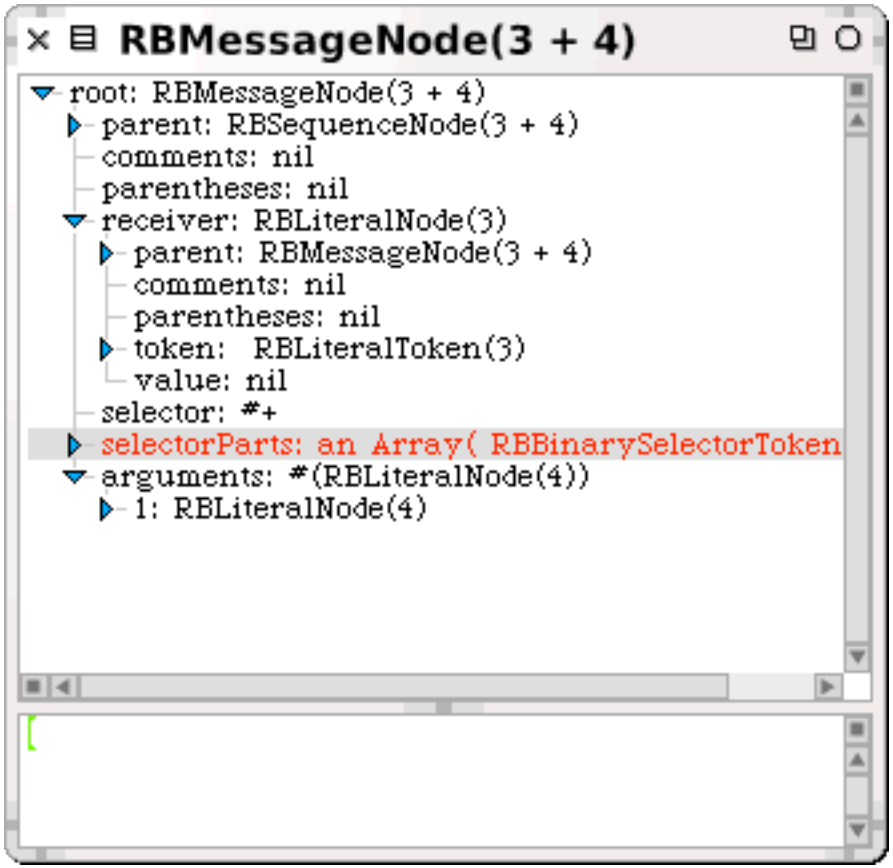
- AST: Abstract Syntax Tree
  - Encodes the Syntax as a Tree
  - Features:
    - Visitors
    - Backward pointers in ParseNodes
    - Encodes formatting
    - Transformation (replace/add/delete)
    - Pattern-directed TreeRewriter
    - PrettyPrinter

```
RBProgramNode
  RBDoItNode
  RBMethodNode
  RBReturnNode
  RBSequenceNode
  RBValueNode
        RBArrayNode
        RBAssignmentNode
        RBBlockNode
        RBCascadeNode
        RBLiteralNode
        RBMessageNode
        RBOptimizedNode
        RBVariableNode
```

# A Simple AST

```
RBParser parseExpression: '3+4'
```

*explore it*



# A Simple Visitor

```
RBProgramNodeVisitor new visitNode: tree
```

Does nothing except walk through the tree

# More Complete Visitor

```
RBProgramNodeVisitor subclass: #TestVisitor
   instanceVariableNames: 'literals'
   classVariableNames: ''
   poolDictionaries: ''
   category: 'Compiler-AST-Visitors'

TestVisitor>>acceptLiteralNode: aLiteralNode
   literals add: aLiteralNode value.

TestVisitor>>initialize
   literals := Set new.

TestVisitor>>literals
   ^literals
```

```
tree := RBParser parseExpression: '3 + 4'.
(TestVisitor new visitNode: tree) literals
```

```
a Set(3 4)
```

# Tree Matcher

- Implementing all Refactorings with visitors
  - Too much work
  - Too low level
- Needed: High level specification of transformations
- Rewrite Engine: Core of Refactoring Engine
- No only useful for Refactoring!

# Tree Matcher

- Describe transformation by using patterns
- Syntax: Smalltalk + Meta Variables
- Example:

```
| `@Temps |
``@.Statements.
``@Boolean ifTrue: [^false].
^true
```

# Meta Variables

All Meta Variables begin with `

| Character | Type | Example |
|---|---|---|
| ` | recurse into | ``@object foo |
| @ | list | \| `@Temps \| `@.statements |
| . | statement | `.Statement |
| # | literal | `#literal |


# Example 1

- Search for:

```
``@object not ifTrue: ``@block
```

- Replace with:

```
``@object ifFalse: ``@block
```

- Explanation:
  - Eliminate an unnecesary not message

# Example 2

- Search for:

```
| `@Temps |
``@.Statements.
``@Boolean ifTrue: [^false].
^true
```

- Replace with:

```
| `@Temps |
``@.Statements.
^``@Boolean not
```

- Explanation:
  - Return the value of the boolean negated instead of using a conditional

# Implementation: Model and Environment

- Model Code transformed but not installed
  - We need to be able to see refactored code without changing the system.
  - RBNameSpace
- Model Classes + Methods
  - Framework duplicates Smalltalk‘s structural Reflection
  - RBClass, RBMethod
- Model Scope to which Refactorings apply
  - RBEnvironment


# Back to Code: Pretty Printer

- Visitor: Walks the AST
- Prints out text for each node

- Problem: How to preserve formatting?
  - AST saves formatting (whitespace, parenthesis)
  - Pretty Printer can use saved formatting information

# Contributions needed

- Improved UI
- Integrated Parser with Squeak NewCompiler
  - Scanner/Parser done with tool (SmaCC)
  - Easier to change / experiment
- Integrated RoelTyper
  - Heuristical type inference
- Better PrettyPrinter
  - Configurability
  - Better Layout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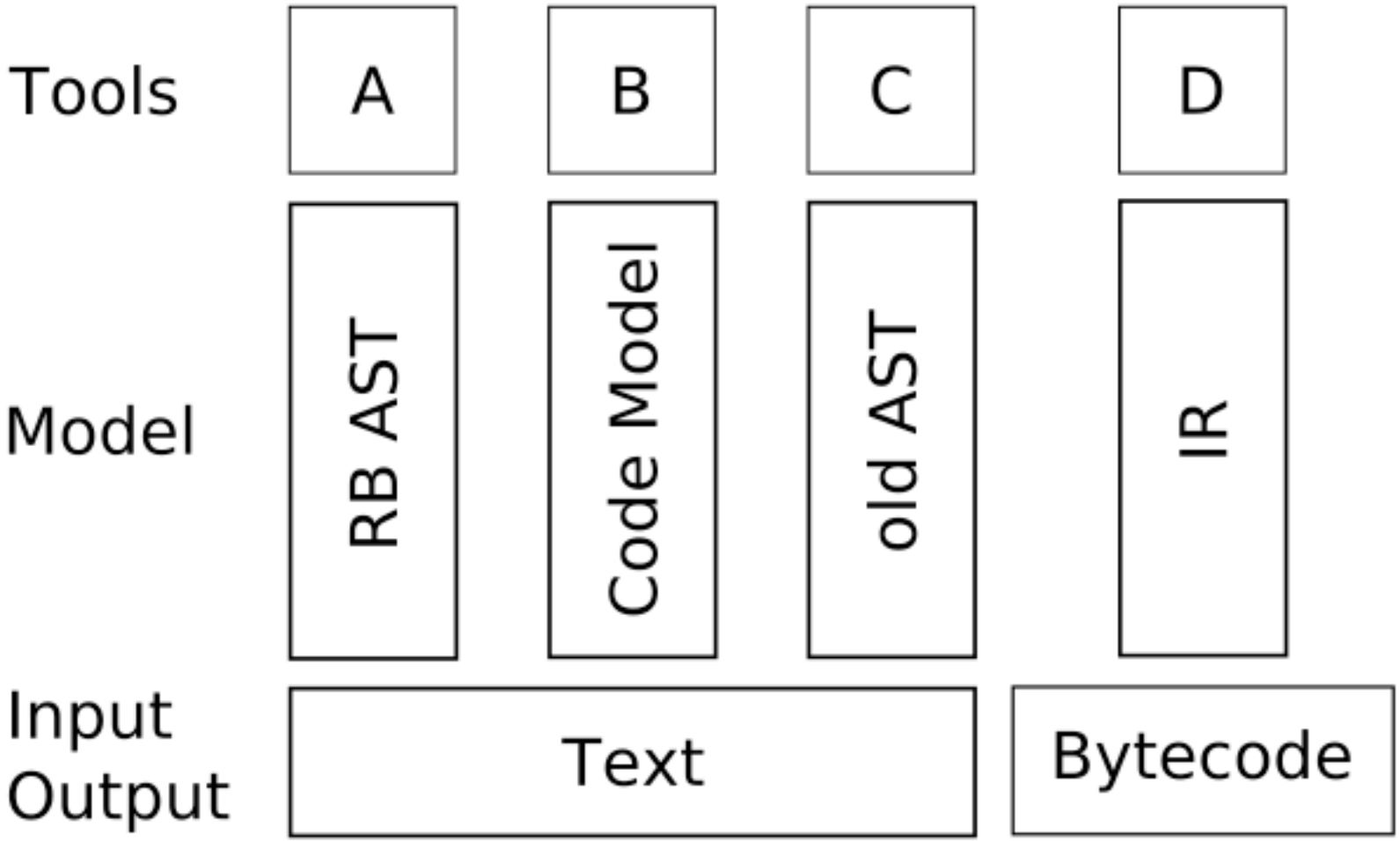
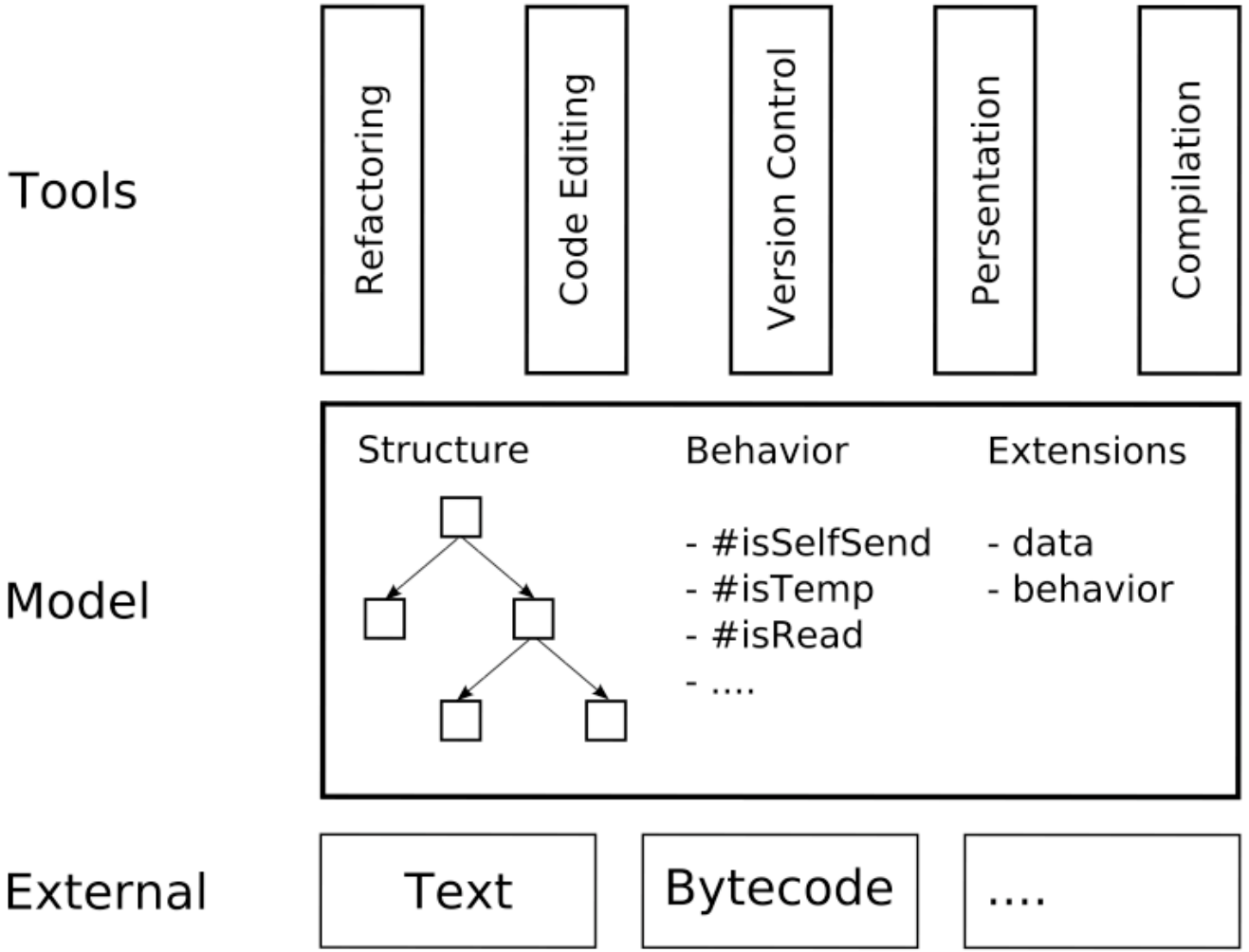
# Reflection?

- We change the system using itself
  - So it‘s Reflection, on some level
- But: Let‘s look again at the definition
  - Model of itself
  - Causally connected
- We Build our own abstraction layer
  - AST + Environment
- This Model is not causally connected!

# State Today


Tools
A
B
C
D
Model
RB AST
Code Model
old AST
IR
Input
Output
Text
Bytecode

# Why not this?


Tools
Refactoring
Code Editing
Version Control
Persentation
Compilation
Model
Structure
Behavior
Extensions
- #isSelfSend
- #isTemp
- #isRead
- ....
- data
- behavior
External
Text
Bytecode
....

# Towards Better Reflection

- High-level sub-method structural reflection

- First prototype: Persephone
  - „AST only“ Smalltalk:
    - causally connected AST
    - Uses RB AST
  - Annotation Framework
  - Provides ByteSurgeon functionality on AST

  - Lots of interesting projects:
    - Presentation framework for annotated code
    - .....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Questions?