

Reflection and Context

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Roadmap

- > **I. Sub-Method Structural Reflection**
- > II. Partial Behavioral Reflection
- > III. Meta Context



Smalltalk

- > Smalltalk has support for reflection
- > Structural reflection
 - Classes / methods are objects
 - Can be changed at runtime
- > Behavioral reflection
 - Current execution reified (`thisContext`)
 - `#doesNotUnderstand` / `MethodWrappers`

Can we do better?

- > Structural Reflection stops at method level
 - Bytecode in the CompiledMethod: Numbers
 - Text: Just a String, needs to be compiled
- > Behavior hard coded in the Virtual Machine
 - Message Sending
 - Variable Access
- > Both structural and behavioral reflection is limited
 - We should do better!

Structural Reflection

- > Structure modeled as objects

- e.g. Classes, methods
- Causally connected

- > Uses:

- Development environments
- Language extensions and experiments

Methods and Reflection

- > Method are Objects
 - e.g in Smalltalk
- > No high-level model for sub-method elements
 - Message sends
 - Assignments
 - Variable access
- > Structural reflection stops at the granularity of methods

Sub-Method Reflection

- > Many tools work on sub method level
 - Profiler, Refactoring Tool, Debugger, Type Checker
- > Communication between tools needed
 - Example: Code coverage
- > All tools use different representations
 - Tools are harder to build
 - Communication not possible

Existing Method Representations

- > Existing representations for Methods
 - Text
 - Bytecode
 - AST

Requirements

- > Causal Connection
- > Abstraction Level
- > Extensibility
- > Persistency
- > Size and Performance

Text

- > **Low level abstraction**
 - String of characters

- > **Not causally connected**
 - Need to call compiler

Bytecode

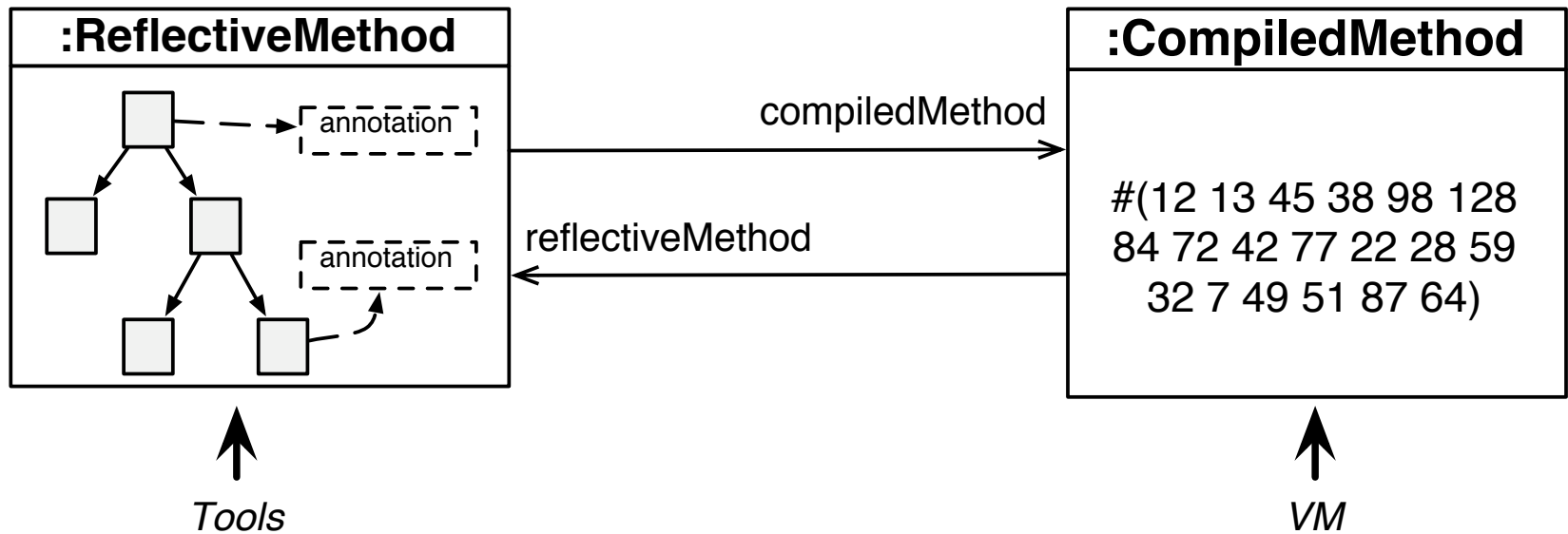
- > Low level abstraction
 - Array of Integers
- > Missing extensibility
 - e.g. for tools
- > Mix of base- and meta-level code
 - Problems with synthesized code when changing code
 - Examples: AOP point-cut residues, reflection hooks

Abstract Syntax Tree

- > Not causally connected
 - Need to call compiler
- > Not extensible
 - Fixed set of codes, no way to store meta data
- > Not persistent
 - Generated by compiler from text, never stored

Solution: Reflective Methods

- > Annotated, persistent AST
- > Bytecode generated on demand and cached



Persephone

- > Implementation of Reflective Methods for Squeak 3.9
- > Smalltalk compiler generates Reflective Methods
 - Translated to bytecode on demand
- > Open Compiler: Plugins
 - Called before code generation
 - Transform a copy of the AST

Requirements revisited

- > Abstraction Level OK
- > Causal Connection OK
- > Extensibility OK
- > Persistency OK
- > Size and Performance OK

Annotations

- > Source visible annotations
 - extended Smalltalk syntax

`(9 raisedTo: 10000) <:evaluateAtCompiletime:>`

- > Source invisible annotations
 - Reflective API
 - Can reference any object
- > Every node can be annotated
- > Semantics: Compiler Plugins

Example: Pluggable Type-System

- > Example for textual annotations

```
bitFromBoolean: aBoolean <:type: Boolean :>  
^ (aBoolean ifTrue: [1] ifFalse: [0]) <:type: Integer :>
```

- > Optional, pluggable type-system
- > Types stored as annotations in the Reflective Methods

Memory

	<i>number of classes</i>	<i>memory</i>
Squeak 3.9	2040	15.7 MB
<i>Persephone no reflective methods</i>	2224	20 MB
<i>Persephone reflective methods</i>	2224	123 MB

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Behavioral Reflection

- > Reflect on the execution
 - method execution
 - message sending, variable access

- > In Smalltalk
 - No model of execution below method body
 - message sending / variable access hard coded by VM
 - #doesNotUnderstand / MethodWrappers

- > Reflective capabilities of Smalltalk should be improved!

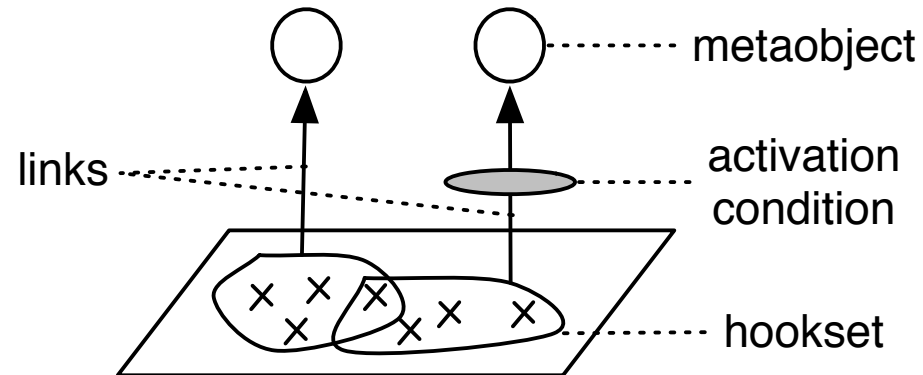
MetaclassTalk

- > Extends the Smalltalk metaclass model
 - Similar to CLOS MOP
- > Metaclass defines
 - message lookup
 - access to instance variables
- > Problems:
 - Reflection only controllable at class boundaries
 - No fine-grained selection (e.g. single operations)
 - Protocol between base and meta level is fixed

Reflex: Partial Behavioral Reflection

- > Hooksets: collection of operation occurrences
- > Links
 - Bind hooksets to meta-objects
 - Define protocol between base and meta

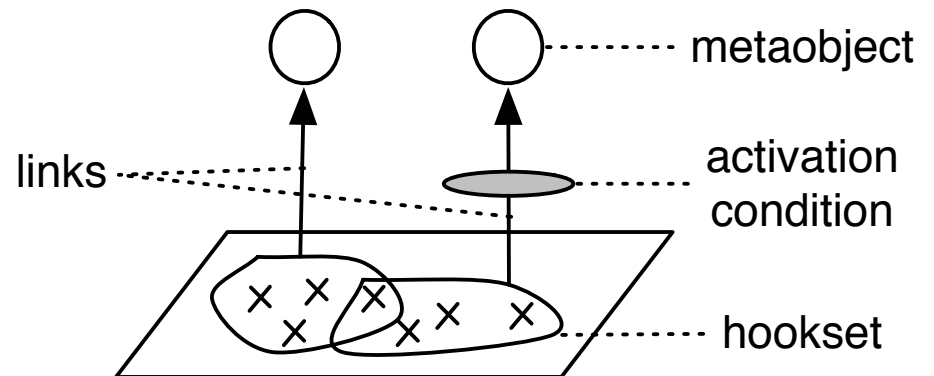
- > Goals
 - Highly selective reification
 - Flexible meta-level engineering
 - *Protocol specification*
 - *Cross-cutting hooksets*



Tanter, OOPSLA03

Example: Profiler

- > Operation:
 - Method execution (around)
- > Hookset:
 - All execution operations in a package
- > Meta-object:
 - A profiling tool



Reflex for Squeak

- > **Partial Behavioral Reflection pioneered in Java**
 - Code transformation at load time
 - Not unanticipated (it's Java...)

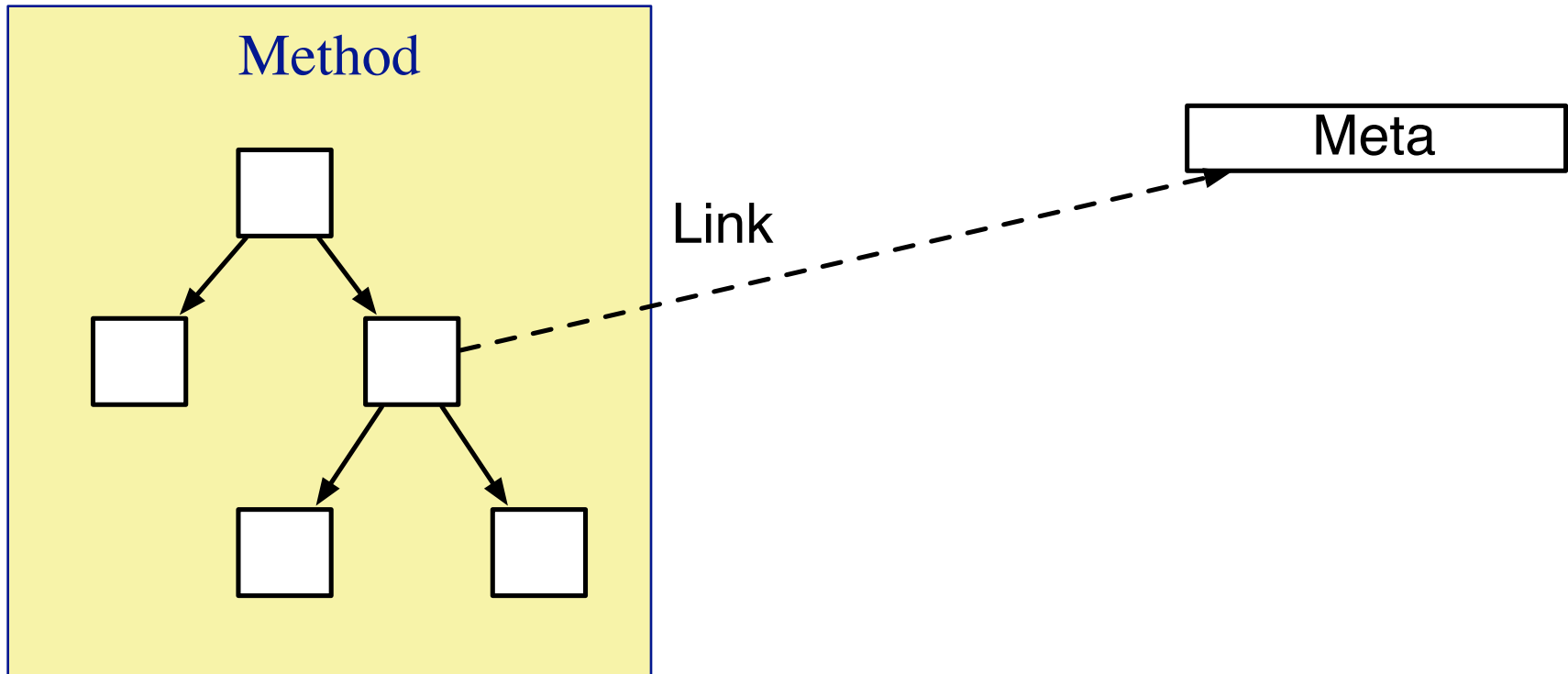
- > **Geppetto: Partial Behavioral Reflection for Smalltalk**
 - For Squeak 3.9 with Bytecode transformation

Problems

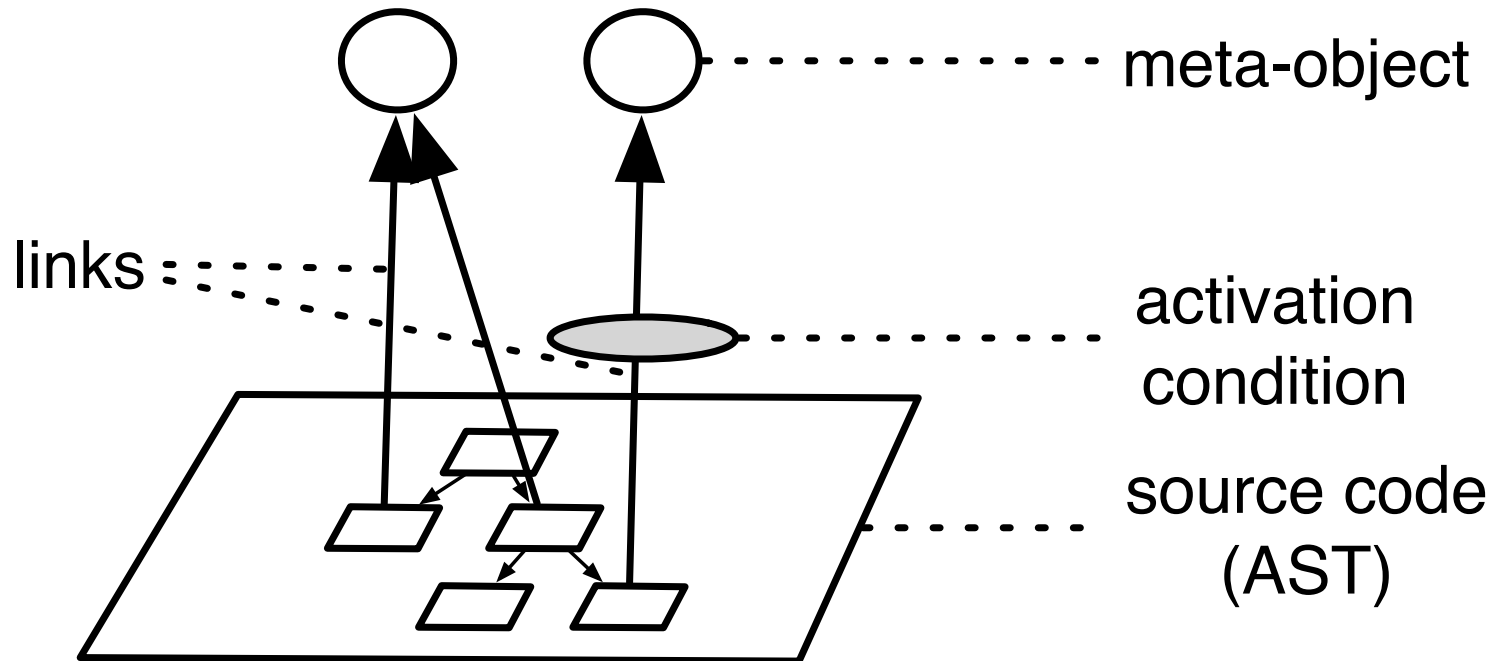
- > Annotation performance
 - Decompile bytecode
- > Execution performance
 - Preambles for stack manipulation
- > Low-level representation
 - ifTrue:ifFalse:
 - Blocks
 - Global variables

Links as Annotations

- > Links can be annotations on the AST

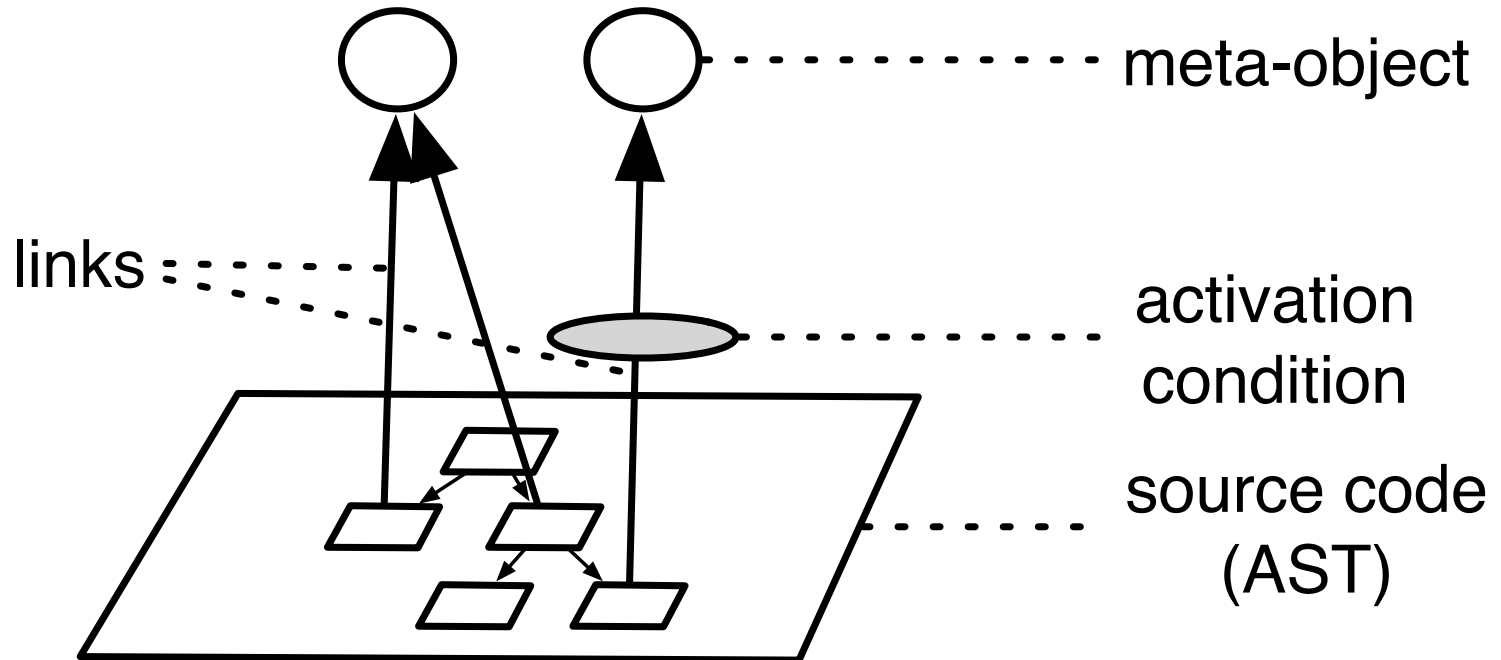


Behavioral Reflection: Flexible



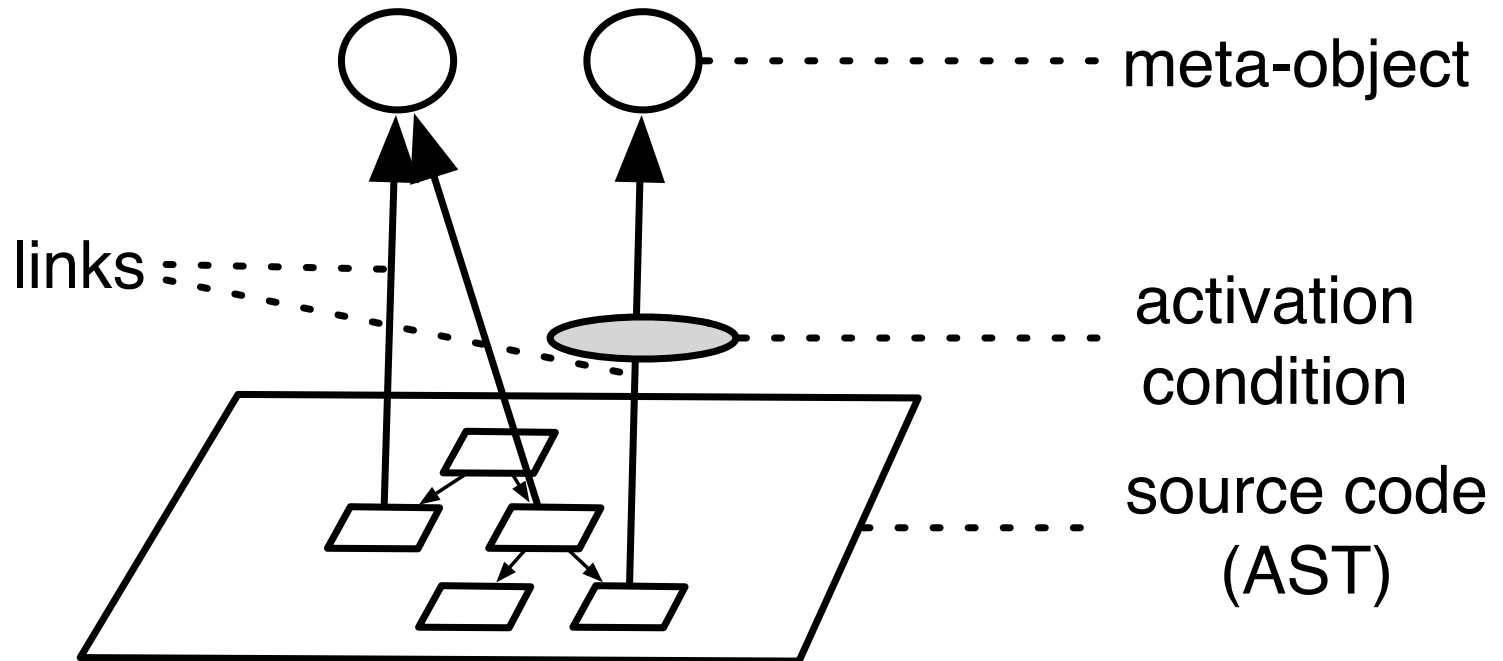
> Very Flexible

Behavioral Reflection: CLOS



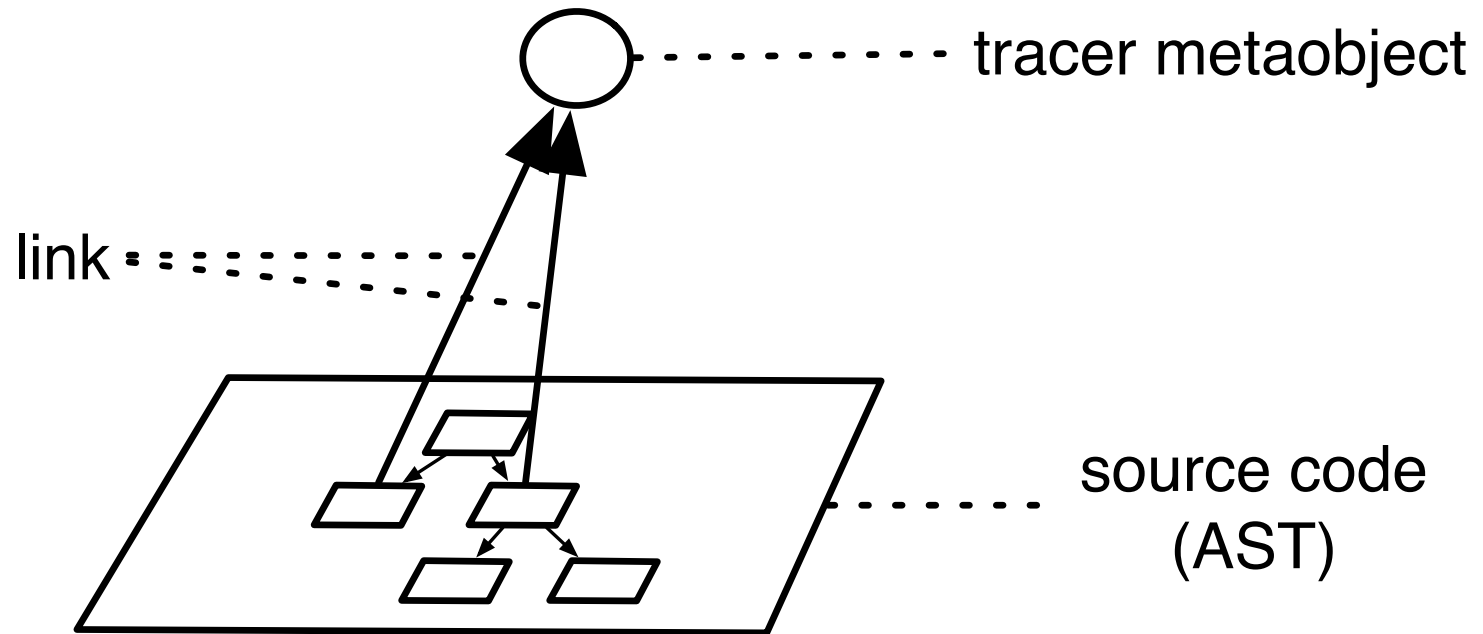
> Meta-class MOP (CLOS)

Behavioral Reflection: AOP



> Aspects

Behavioral Reflection: Tracer



> Tracer

Properties

- > **Very fast annotations**
 - No decompile!
- > **On-the-fly code generation**
 - Only code executed gets generated
- > **Generated code is fast**
 - Better then working on bytecode level

Demo

> Show Bounce Demo

Reflectivity

- > Prototype implementation in Squeak

- Sub-Method Structure
- Partial Behavioral Reflection

- > Download:

<http://scg.unibe.ch/Research/Reflectivity>

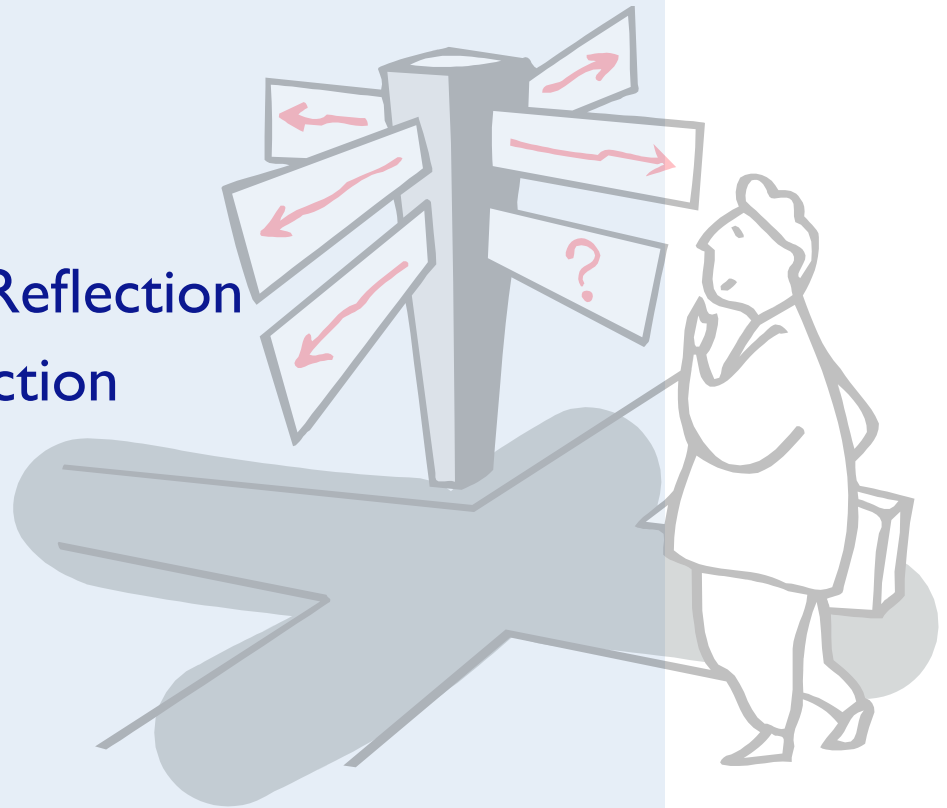
Reflectivity: Pharo

> Not yet...

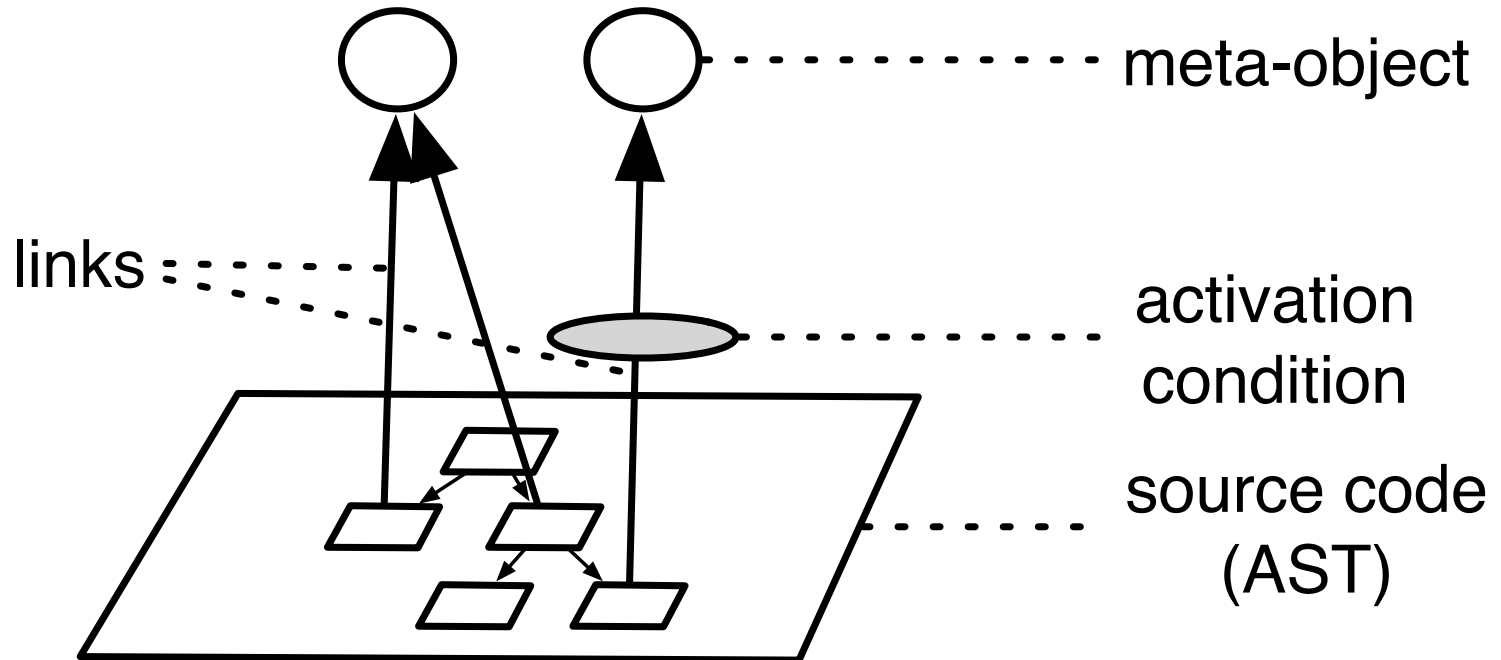
- Now we can do it for real!
 - *Engineering vs. Research...*

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Behavioral Reflection: Flexible



> Let's use it!

Problem: Recursion

- > Behavioral reflection cannot be applied to the whole system
 - System classes
 - Meta-objects

Example: Beeper

> Call the Beeper from `OrderedCollection>>#add`

```
beepLink := Link new metaObject: Beeper.  
beepLink selector: #beep.
```

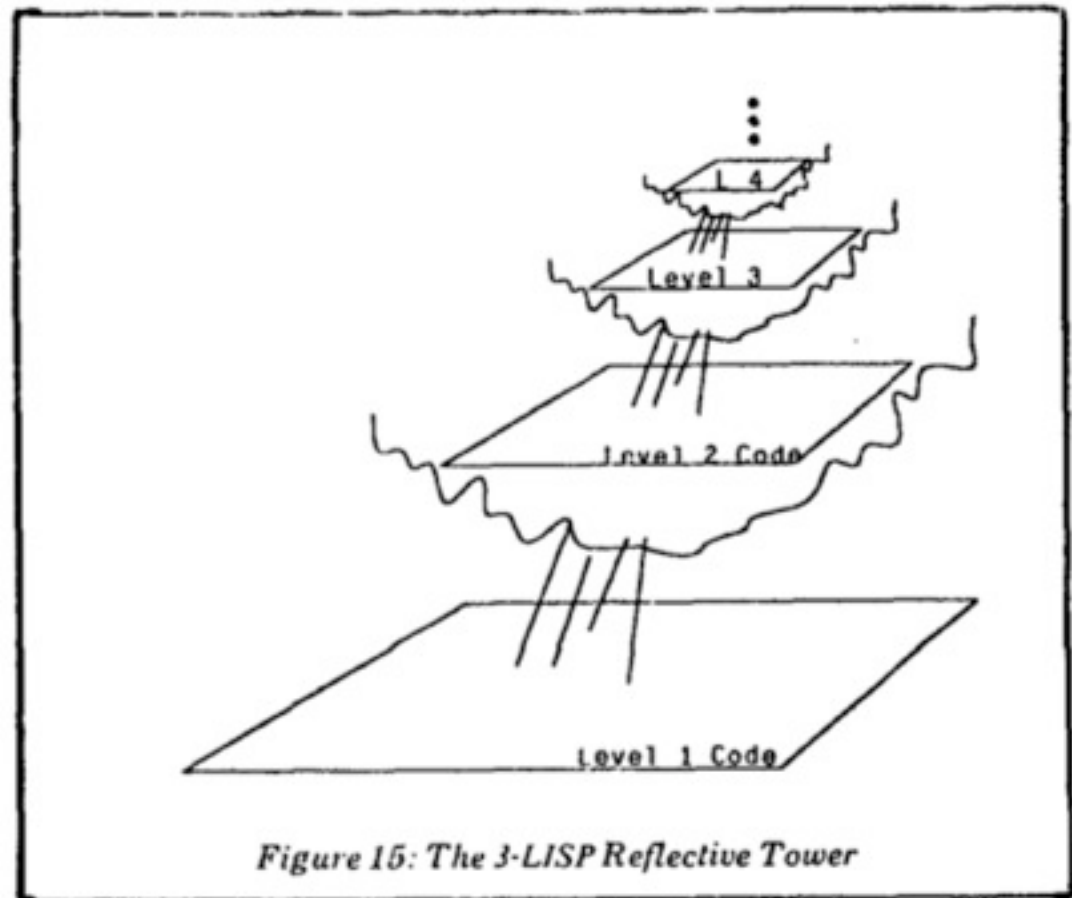
```
(OrderedCollection>>#add:) methodNode link: beepLink.
```


Ad-hoc Solutions

- > Code duplication
- > Adding special tests

Tower of Interpreters

> Smith, 1982

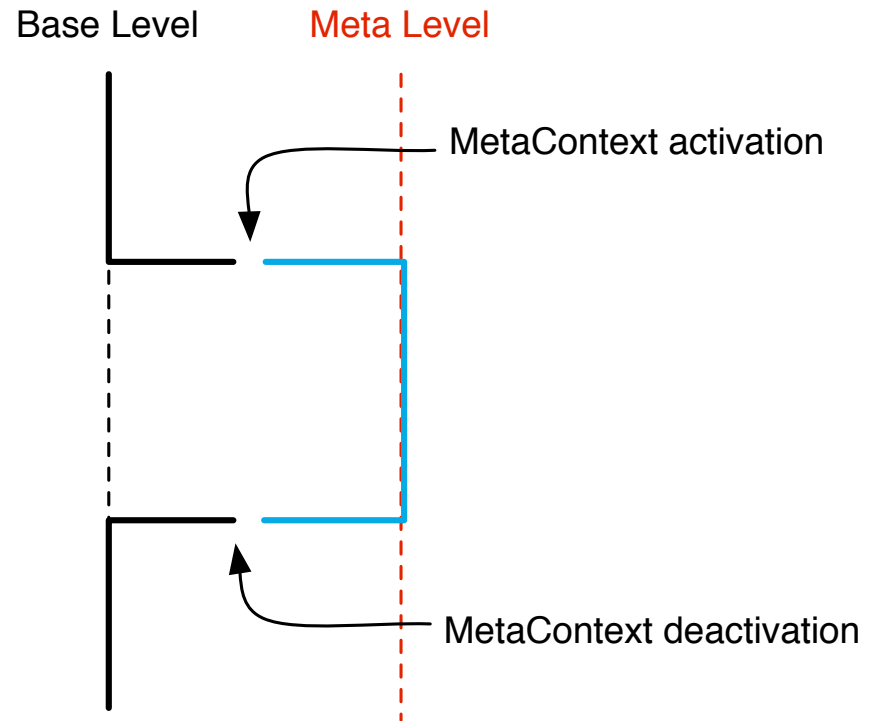


The Real Problem

Representing Meta-Level Execution

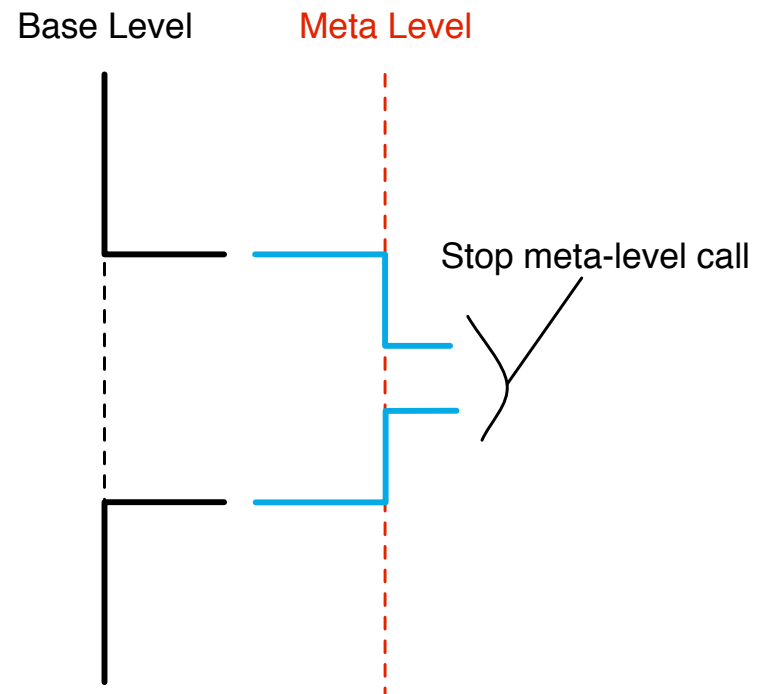
The Meta-Context

- > Link enables **MetaContext**



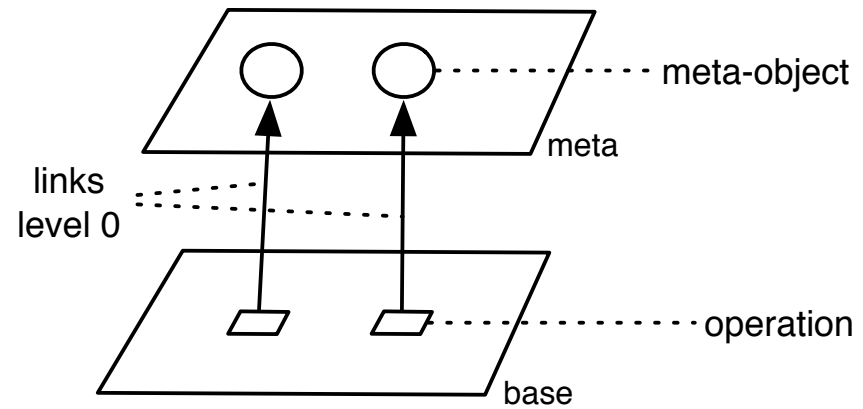
Context-aware Links

- > Disable call when already on the meta-level



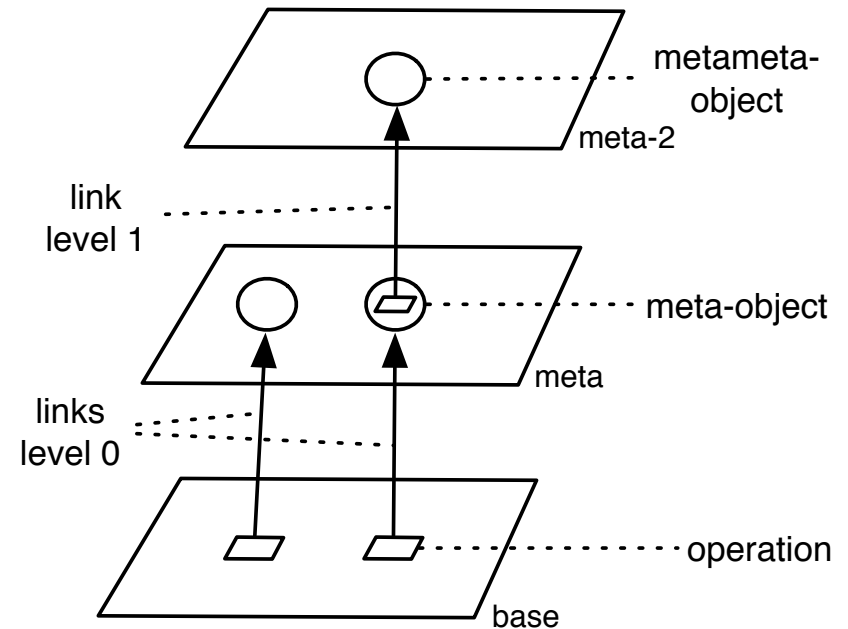
MetaContext

- > Recursion problem solved



MetaContext

- > Meta-level analysis:
 - Trace the tracer



MetaContext

- > Recursion problem
- > Missing representation of meta-level execution
- > Meta-context
 - Solves the recursion problem
 - Enables *meta-level analysis*

Rethinking Reflection

- > Meta change “shows through”
 - Introspection shows implementation
 - Recursion and confusion of meta levels

- > Reflective change is always global
 - Any change is visible to the whole system
 - No way to batch multiple changes into one atomic operation

Next steps

- > Generalize context model:
 - Beyond context as control flow.
- > Virtual machine support... to make it practical
- > What is the next reflective language kernel?

A lot of open questions...

thats why it is

Research...

?????

Questions



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