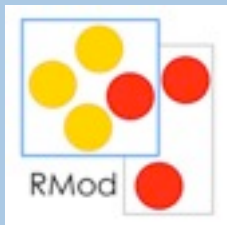


Reflection and Context

Marcus Denker

marcus.denker@inria.fr

<http://rmod.lille.inria.fr>



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

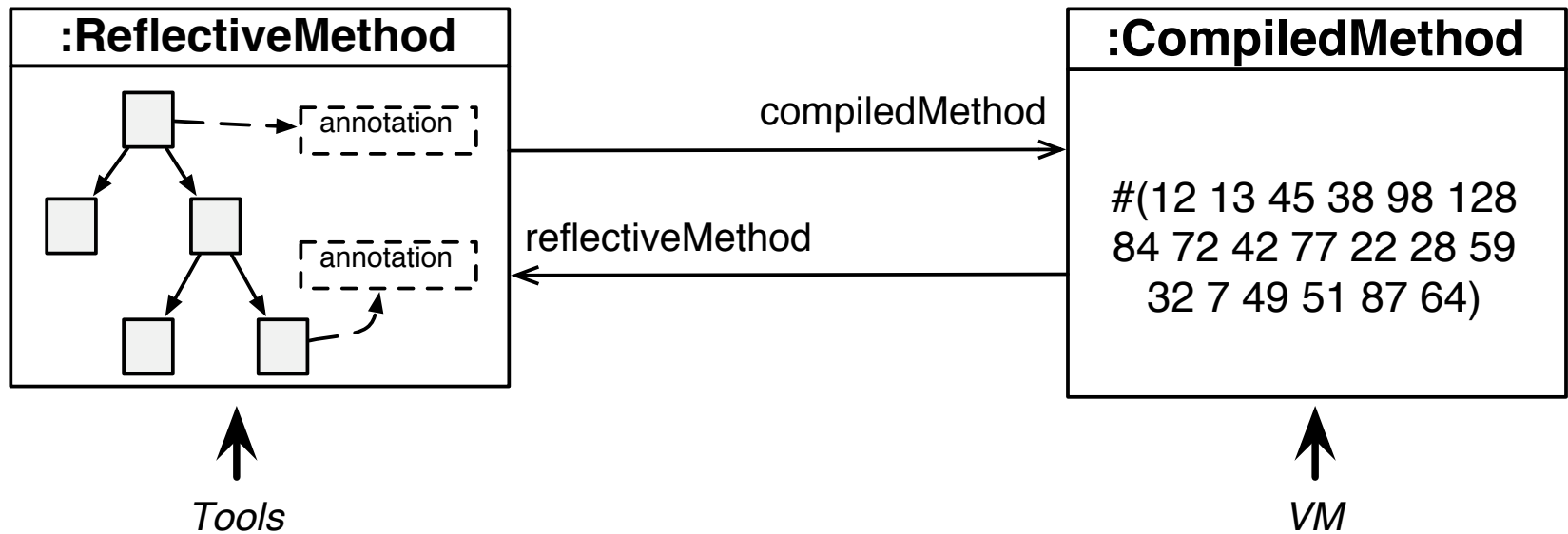
- > Low level abstraction
 - Array of Integers
- > Missing extensibility
 - e.g. for tools
- > Mix of base- and meta-level code
 - Problems with synthesized code when changing code
 - Examples: AOP point-cut residues, reflection hooks

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

Roadmap

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



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!

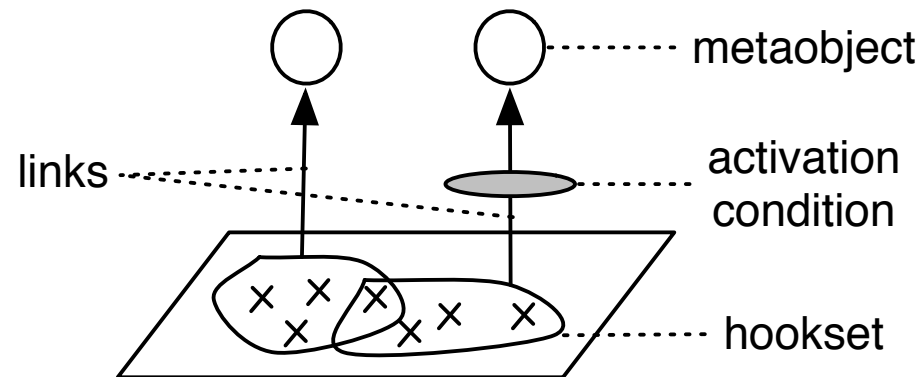
MetaclassTalk

- > 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

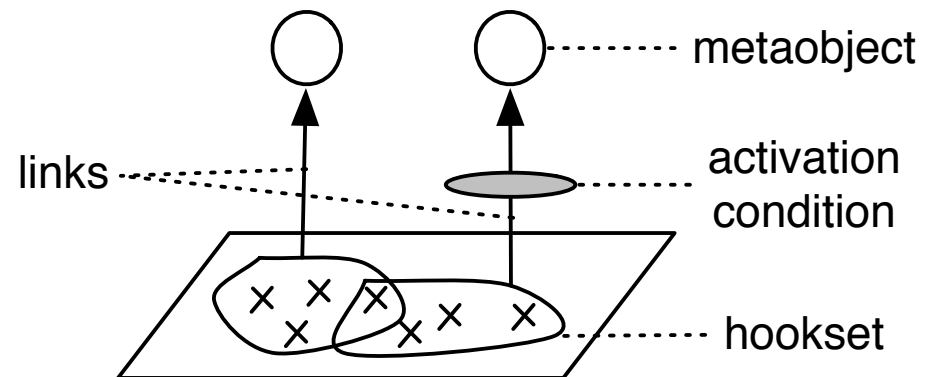
- > Goals
 - Highly selective reification
 - Flexible meta-level engineering
 - *Protocol specification*
 - *Cross-cutting hooksets*



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...)

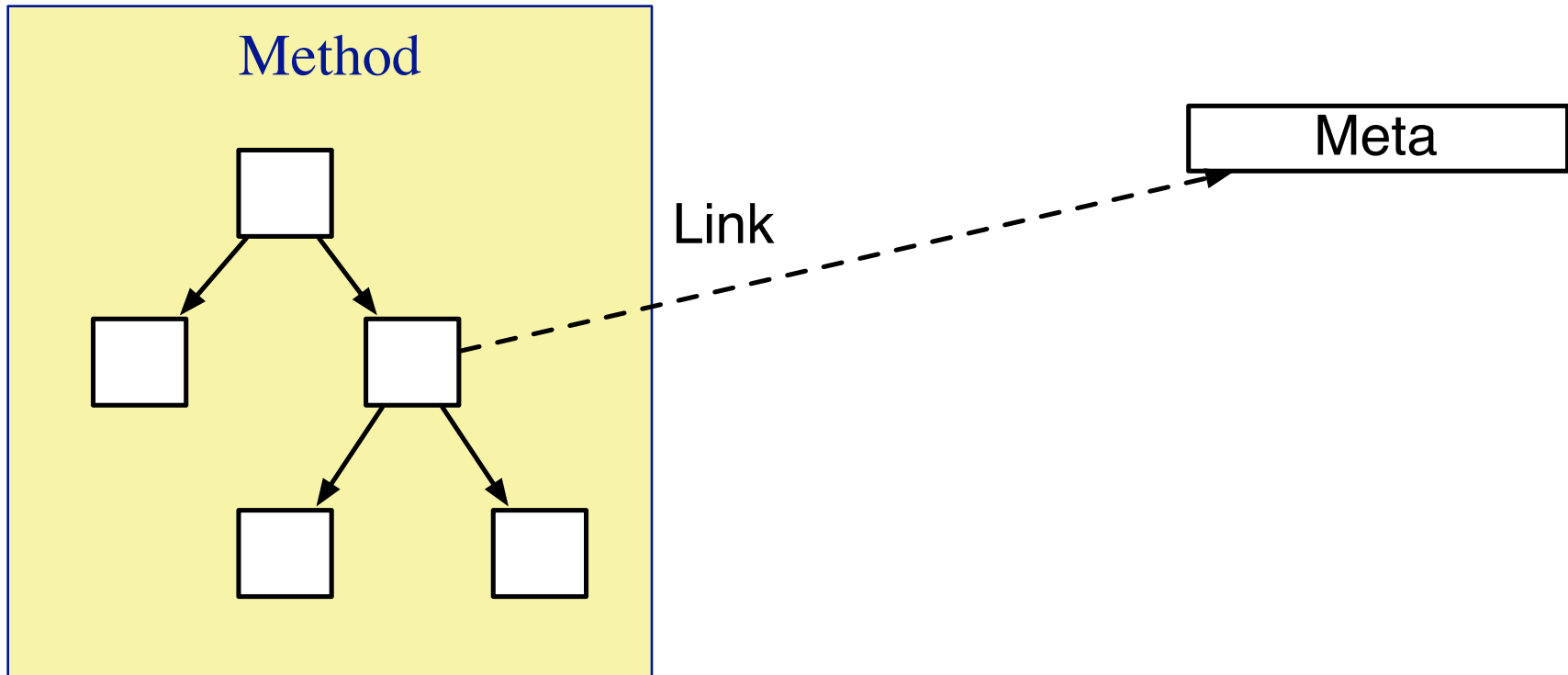
- > **Geppetto: Partial Behavioral Reflection for Smalltalk**
 - For Squeak 3.9 with Bytecode transformation

Problems

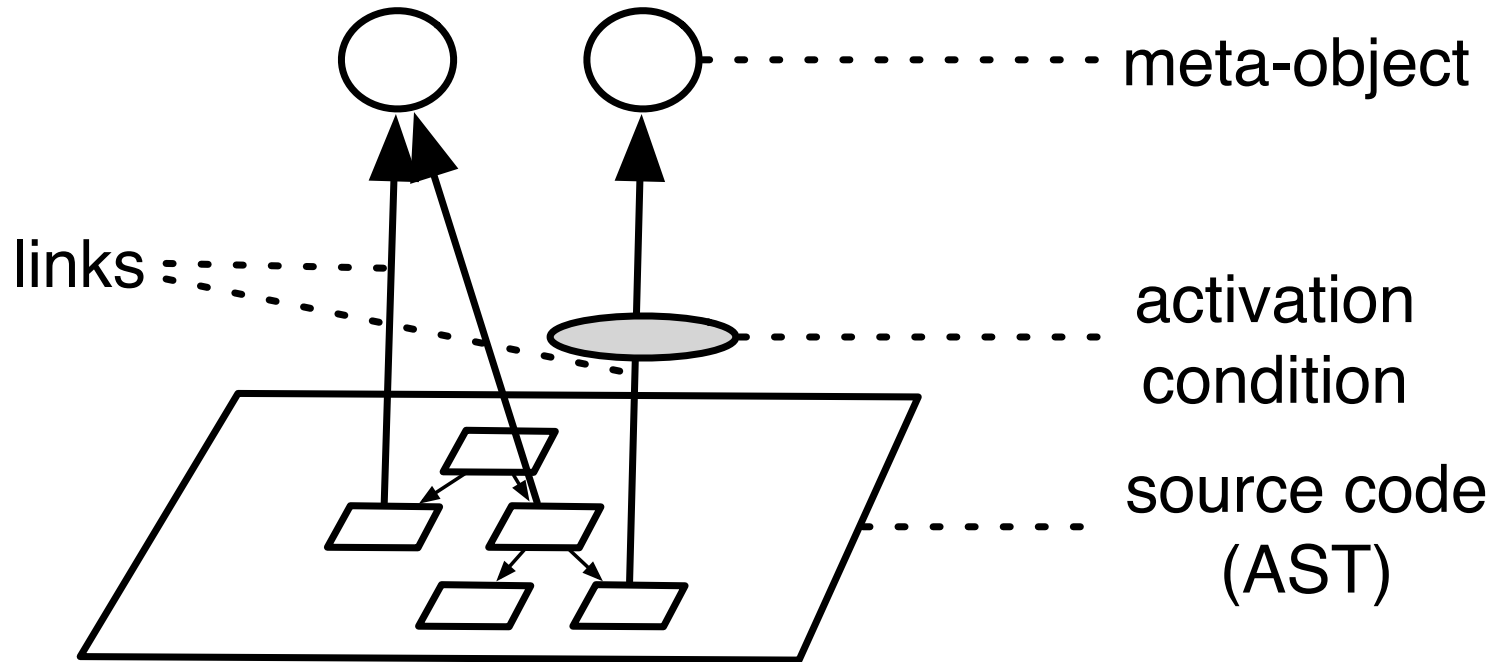
- > Annotation performance
 - Decompile bytecode
- > Execution performance
 - Preambles for stack manipulation
- > Low-level representation
 - ifTrue:ifFalse:
 - Blocks
 - Global variables

Links as Annotations

- > Links can be annotations on the AST

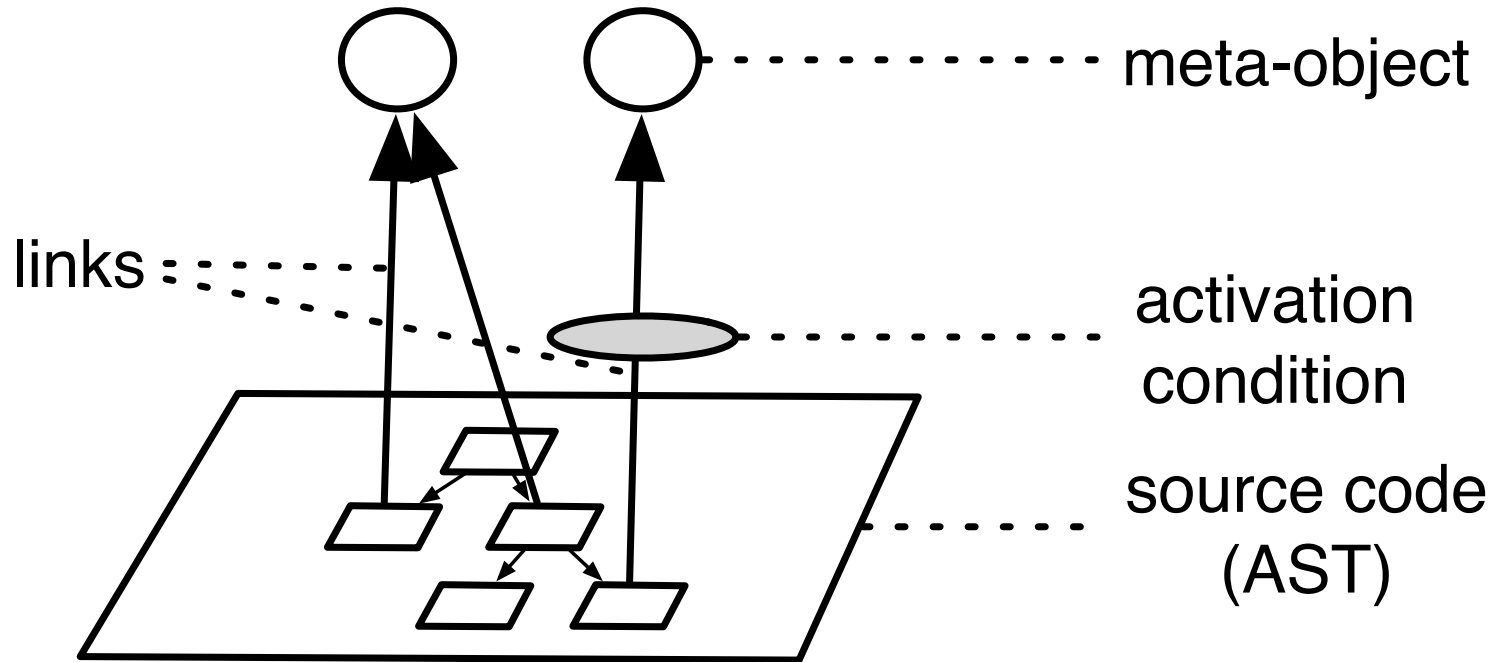


Behavioral Reflection: Flexible



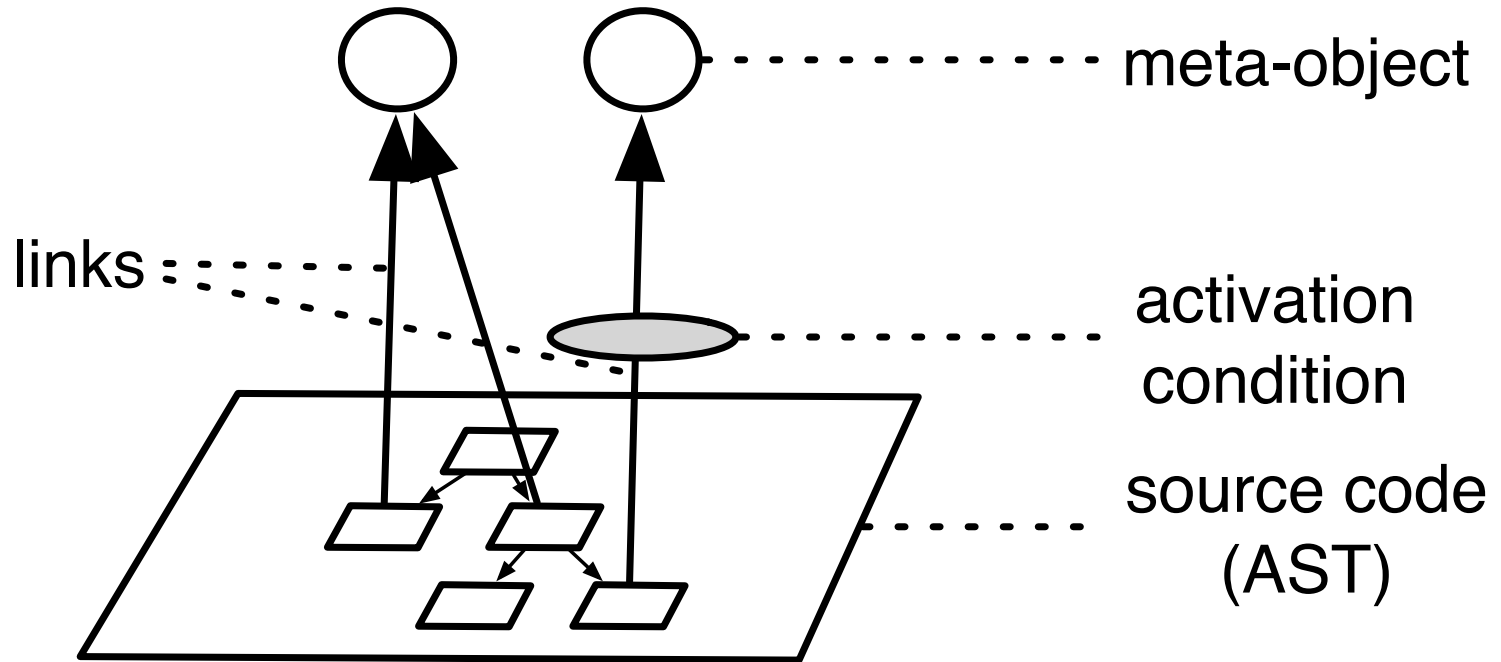
> Very Flexible

Behavioral Reflection: CLOS



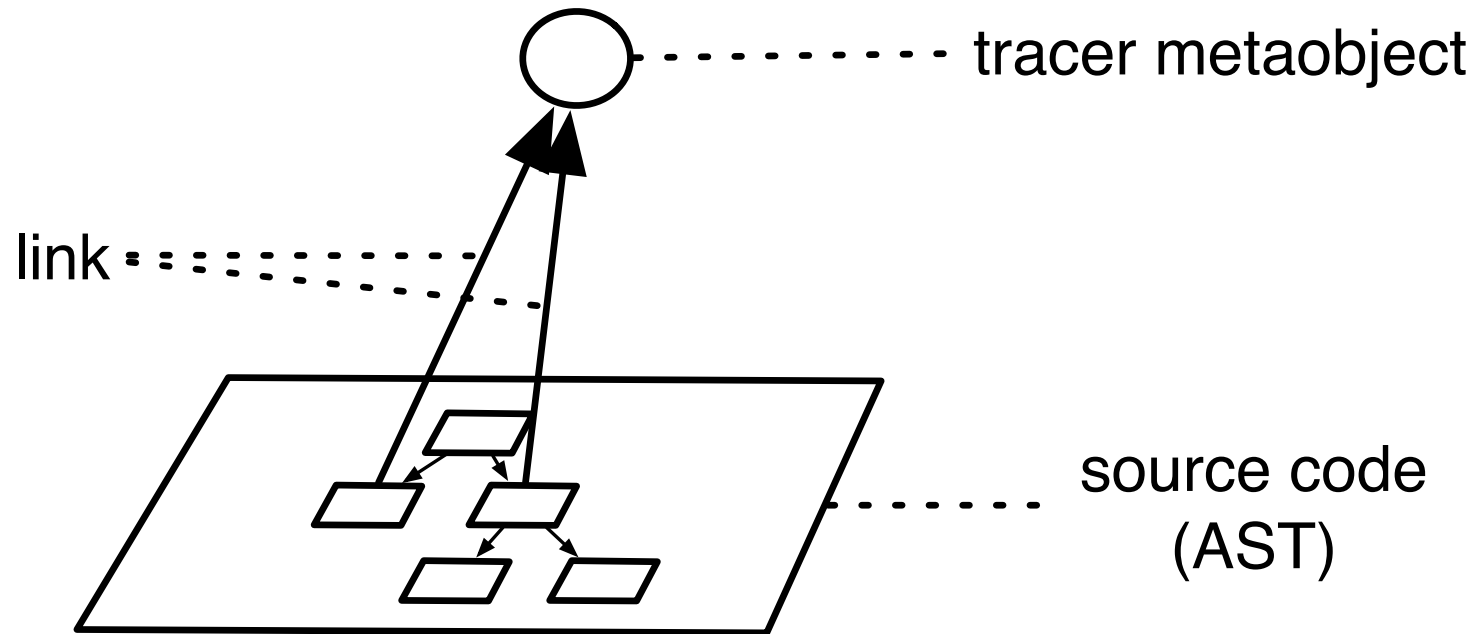
> Meta-class MOP (CLOS)

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:

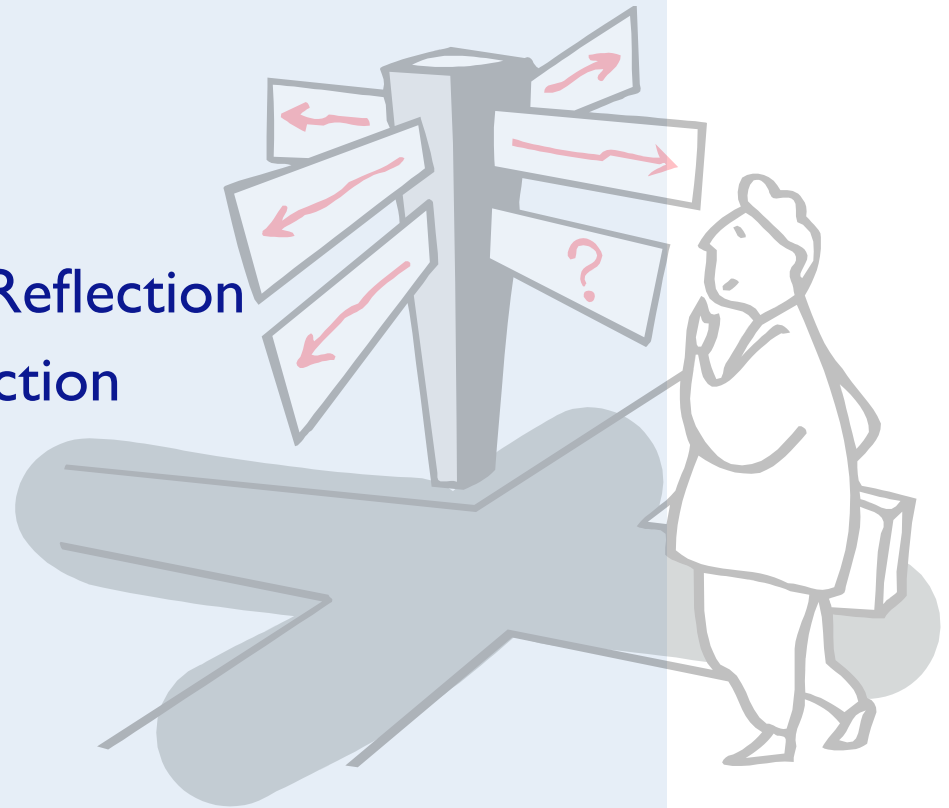
<http://scg.unibe.ch/Research/Reflectivity>

Reflectivity: Pharo

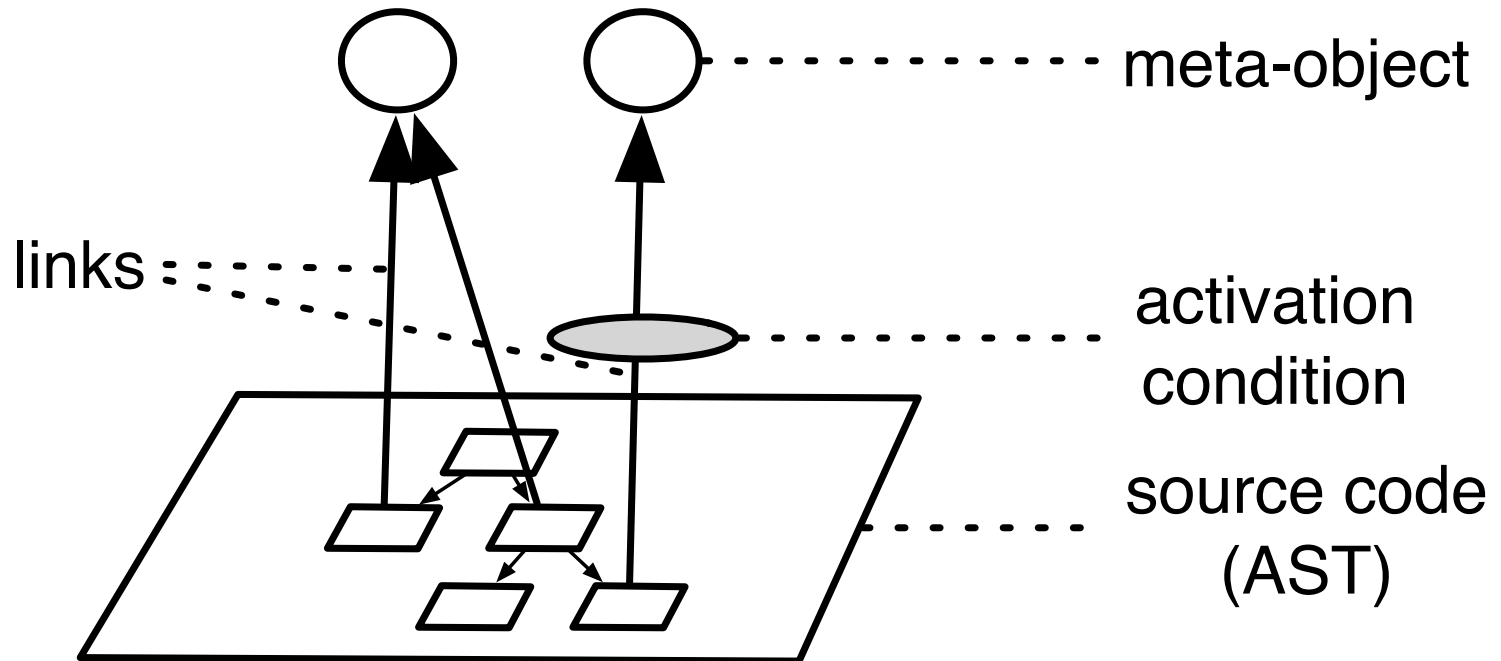
- > Not yet.... but soon.
 - Slowly revisiting all research stuff
 - Now we can do it for real!
 - *Engineering vs. Research...*

Roadmap

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



Behavioral Reflection: Flexible



> Let's use it!

Problem: Recursion

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

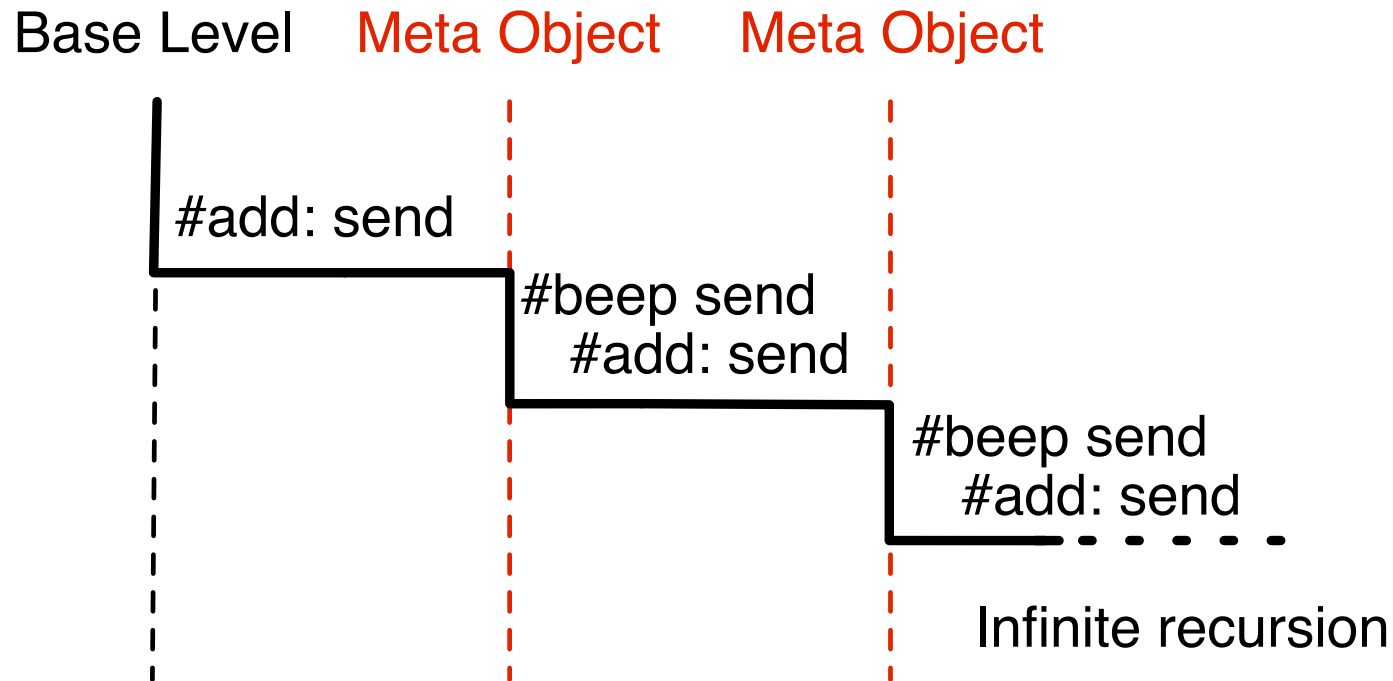
Example: Beeper

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

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

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

Meta-object Call Recursion

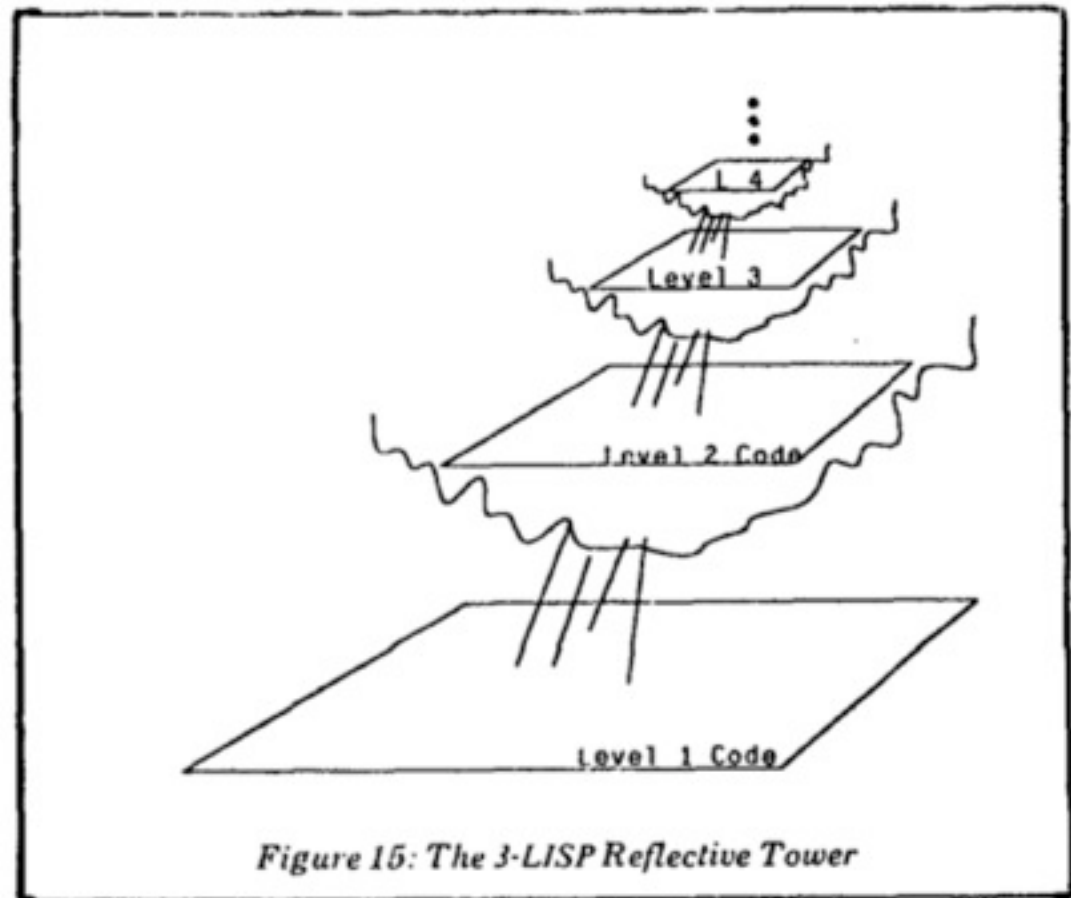


Ad-hoc Solutions

- > Code duplication
- > Adding special tests

Tower of Interpreters

> Smith, 1982

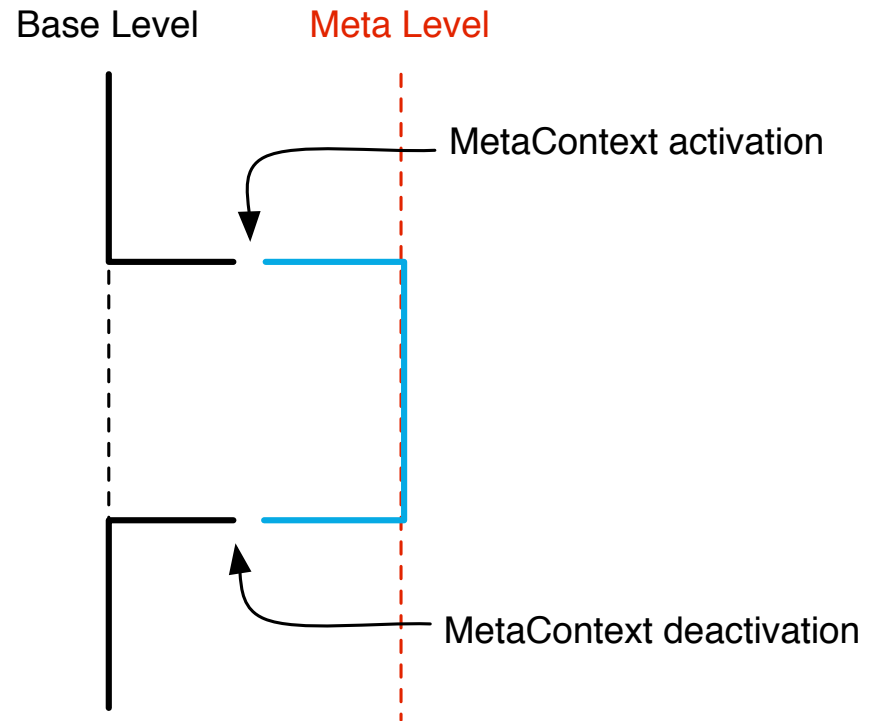


The Real Problem

Representing Meta-Level Execution

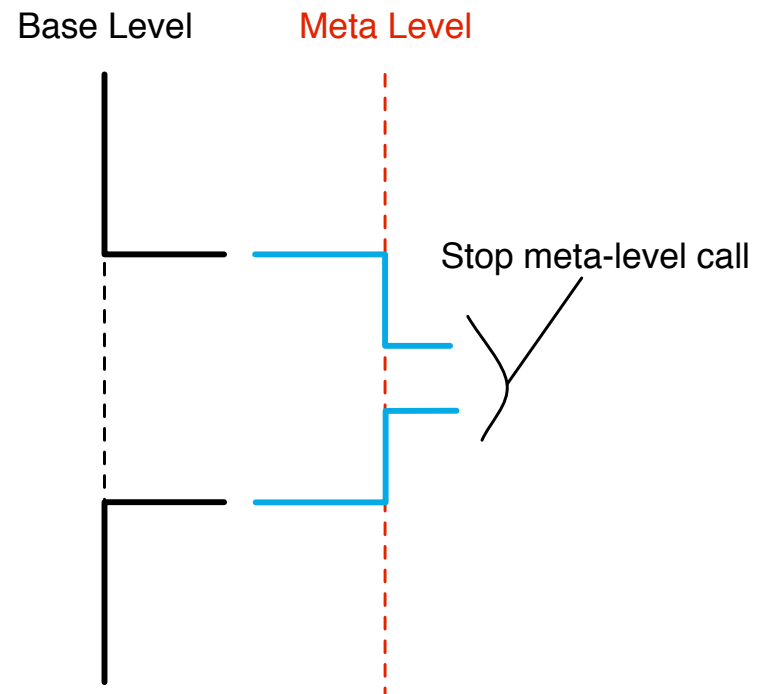
The Meta-Context

- > Link enables **MetaContext**



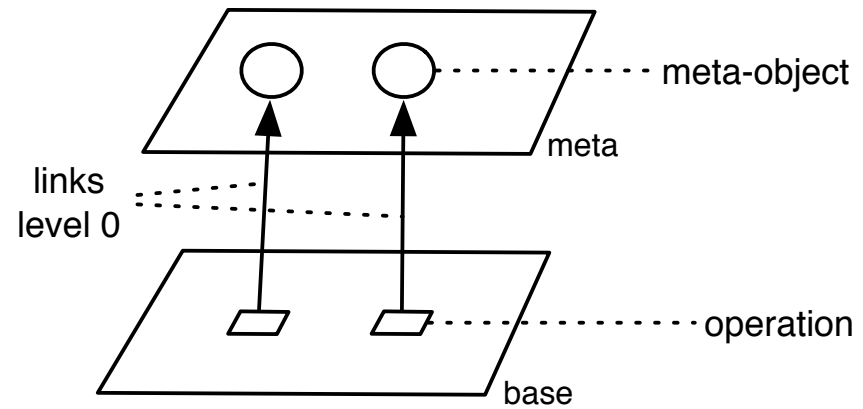
Context-aware Links

- > Disable call when already on the meta-level



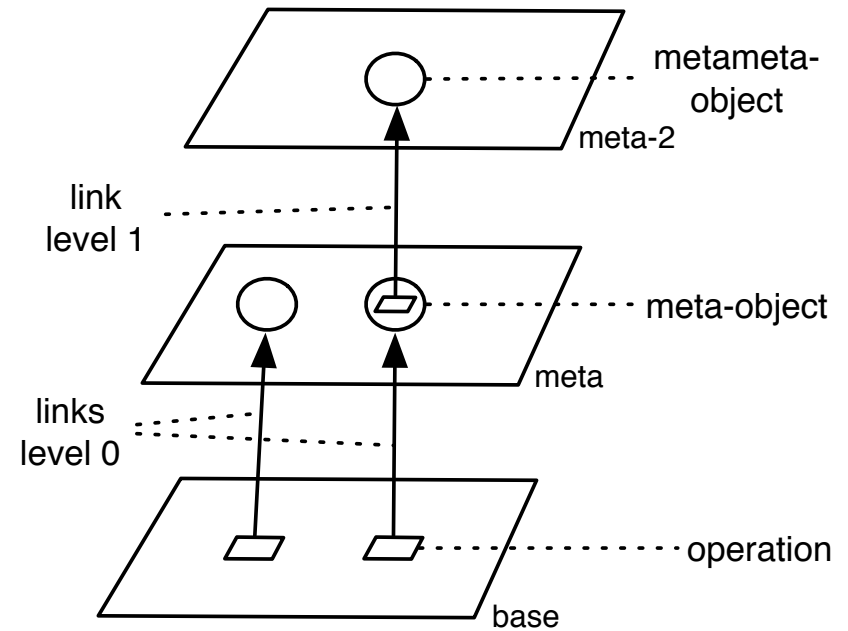
MetaContext

- > Recursion problem solved



MetaContext

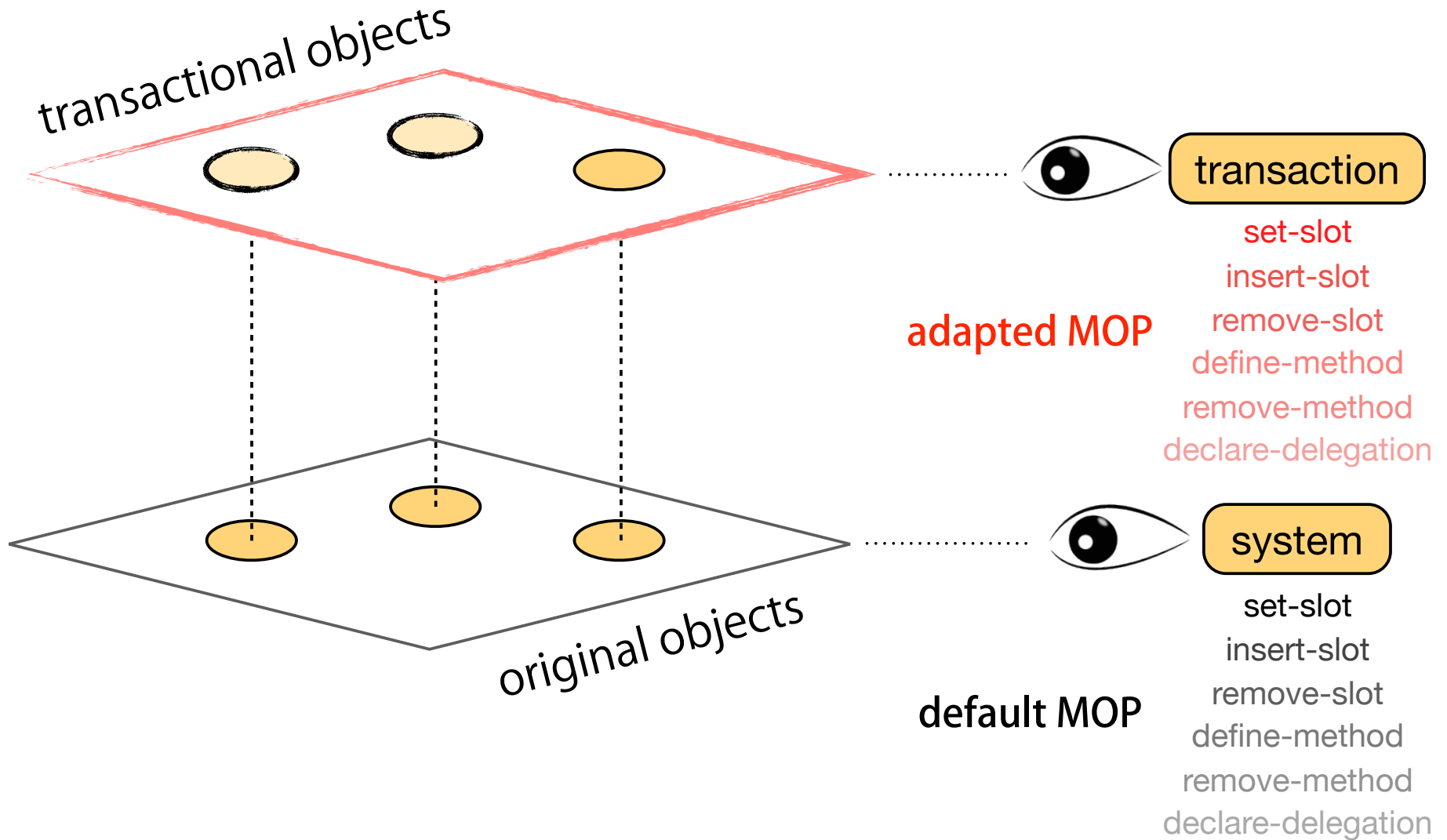
- > Meta-level analysis:
 - Trace the tracer



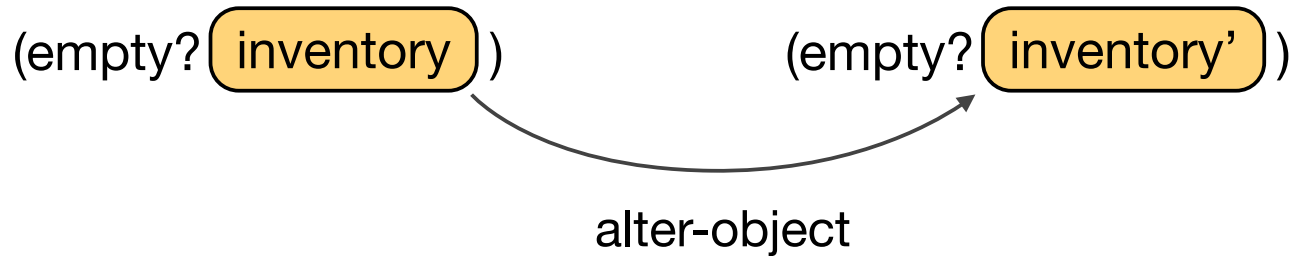
MetaContext

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

adapt reflective behaviour to transactional contexts



non-destructive operations also need to see the objects belonging to the current transaction



(with-context @transaction

(defmethod send (selector arguments)

(let ((log (log (host-context))))

(do-slots (arguments argument index)

(setf (`$slot-value` arguments index) (`gethash` argument log `argument`))))

(resend)))

case study is not implemented
purely on top of the object model

– System must make sure that any method invoked in transaction context sees the transactional versions of modified objects, rather than the original versions.

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



License

> <http://creativecommons.org/licenses/by-sa/2.5/>



Attribution-ShareAlike 2.5

You are free:

- to copy, distribute, display, and perform the work
- to make derivative works
- to make commercial use of the work

Under the following conditions:



Attribution. You must attribute the work in the manner specified by the author or licensor.



Share Alike. If you alter, transform, or build upon this work, you may distribute the resulting work only under a license identical to this one.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

Your fair use and other rights are in no way affected by the above.