

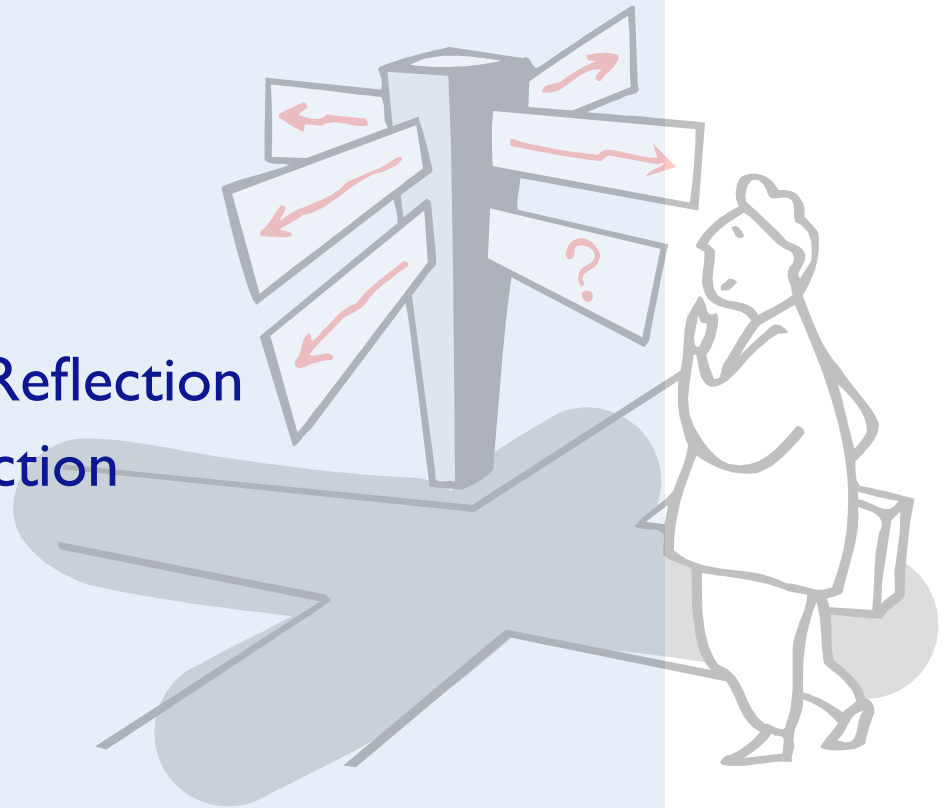
Reflection

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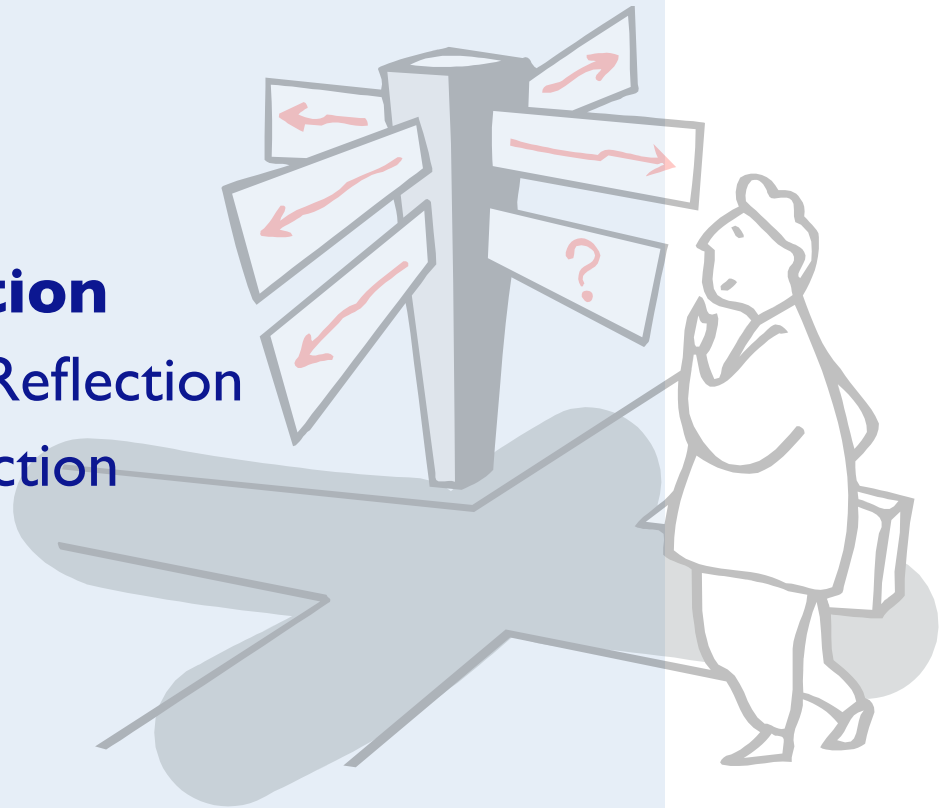
Roadmap

- > Introduction: Reflection
- > I. Sub-Method Structural Reflection
- > II. Partial Behavioral Reflection

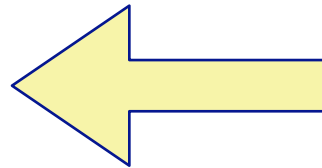


Roadmap

- > **Introduction: Reflection**
- > I. Sub-Method Structural Reflection
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Reflection



```
004-StringZippedAndTest-md.1.cs
'From Squeak3.9 of 7 November 2006 [latest update: #7067] on 5 February 2007 at 3:25:56 pm'
"Change Set: StringZippedAndTest-md
Date: 5 February 2007
Author: Marcus Denker

String has #unzipped, but no #zipped. This
cs adds String->zipped (originally from Diego Gomez Deck) and a test for unzipped/zipped.

This changeset is neutral to the question of zipped/unzipped being in String, but if there is
#unzipped, there should be #zipped. And there should be a test.
"!

!String methodsFor: 'converting' stamp: 'dgd 11/26/2005 21:59'!
zipped
| stream gzipstream |

stream := #BinaryOrTextStream on: String new.

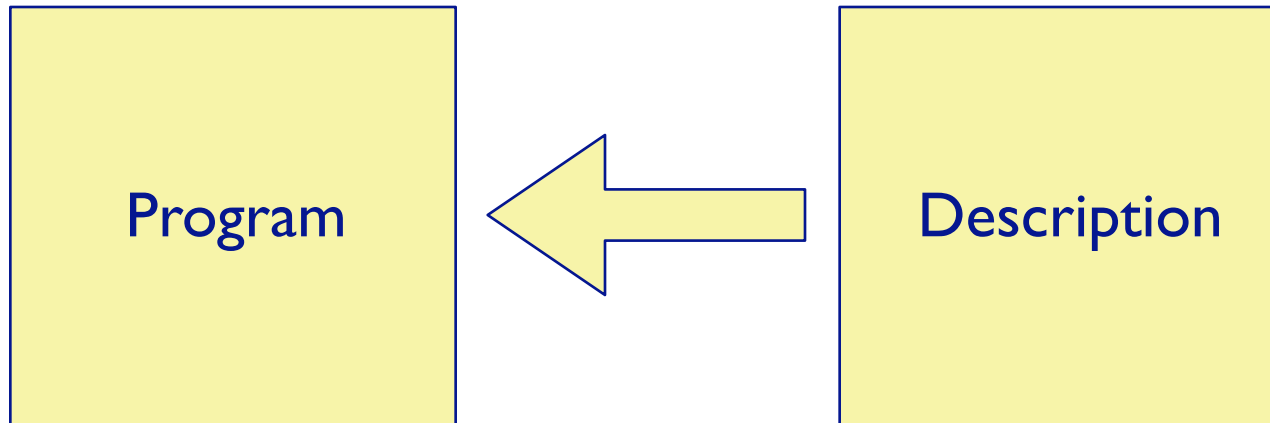
gzipstream := GZipWriteStream on: stream.
gzipstream nextPutAll: self.
gzipstream close.
stream reset.

^ stream contents.
!!

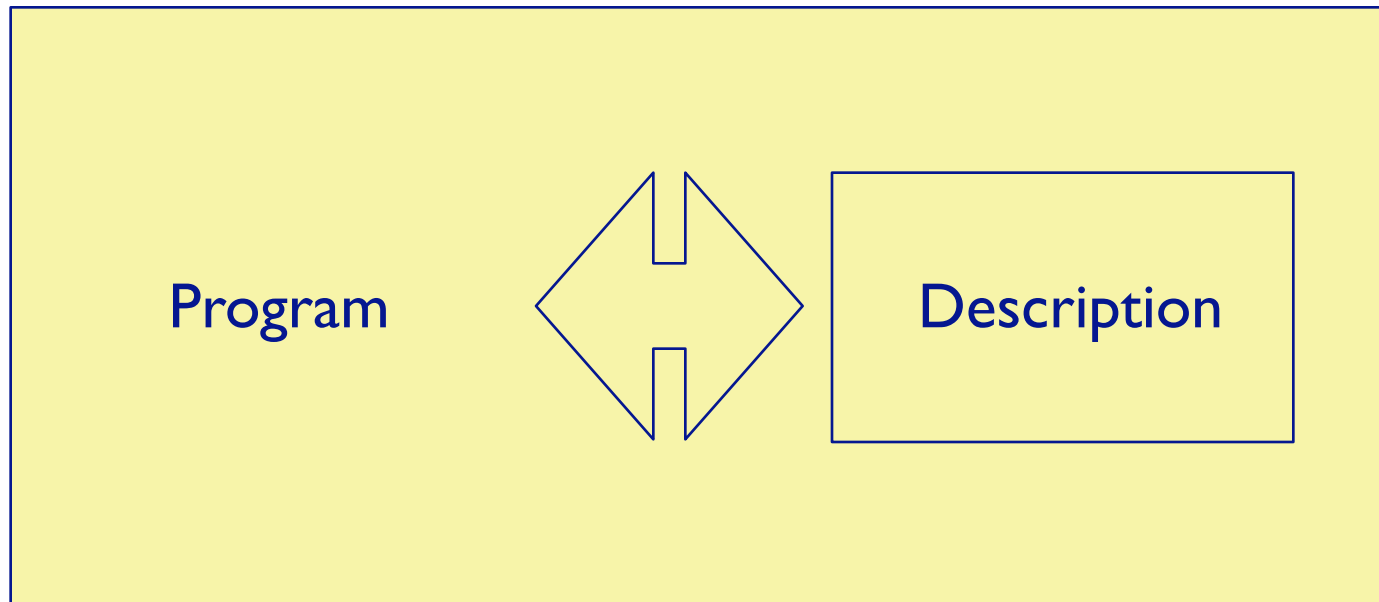
!StringTest methodsFor: 'tests - converting' stamp: 'md 2/5/2007 15:21'!
testZipped
| compressed |

compressed := 'hello' zipped.
self assert: (compressed unzipped = 'hello').! !
```

Reflection



Reflection



Query and **Change**

Why?

The Systems of the future...

- > ... are getting larger and more complex
- > ... are getting more and more dependent on each other
- > **The demands are changing**

Examples of New Demands

- > **Dynamic Analysis**
 - Fine-grained selection
 - Install / retract at runtime
 - Complete system

- > **Development Environment**
 - Complete representation of the system
 - Extensible

System

Definition:

A **computational system** is a computer-based system whose purpose is to answer questions and/or support actions about some domain.

(P. Maes, "Concepts and Experiments in Computational Reflection," Proceedings of OOPLA 87)

Causally Connected

Definition:

A system is said to be **causally connected** to its domain if the internal structures and the domain they represent are linked in such a way that if one of them changes, this leads to a corresponding effect of the other.

(Patty Maes, OOPSLA 87)

Reflective System

Definition:

A **reflective system** is a system which incorporates causally connected structures representing (aspects of) itself.

(Patty Maes, OOPSLA 87)

Introspection

- > **Introspection**
 - Self-representation can be queried
- > **Intercession**
 - Self-representation can be changed

Reflection = Introspection + Intercession

Structure and Behavior

> Structural Reflection

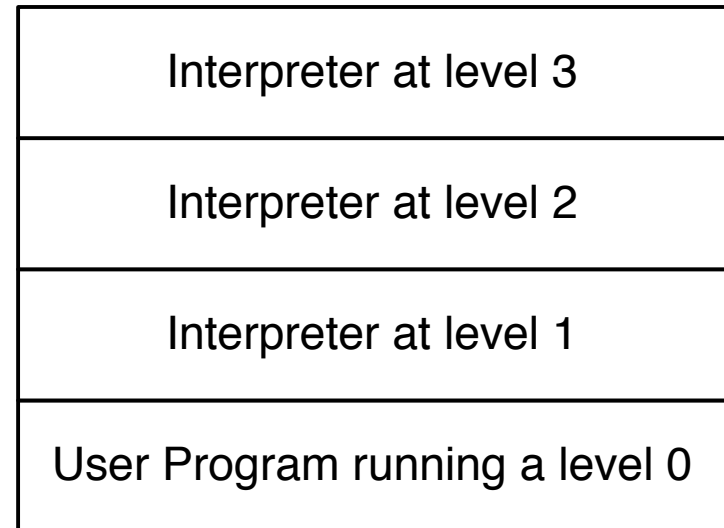
- Concerned with static structure
- For example: packages, data-types, procedures

> Behavioral Reflection

- Concerned with execution
- For example: procedure execution, assignment, variable read

Tower of Interpreters

- > First studied for procedural languages
- > David A. Smith: 3Lisp
- > Tower-of-Interpreters
- > Theoretical. Slow!



Reflection and OOP

- > A good match: self-representation build of objects
 - Better than interpreter data-structures
- > Language-based reflection
 - Language entities represented as objects
 - Meta-objects describe behavior of base level objects
- > Structure: classes/methods are objects
- > Behavior: meta-objects define behavior
 - Example: meta-class defines method lookup

Example: Java

- > Structural introspection
 - `java.lang.reflect`
 - Query a model of the program (classes, protocols)
- > Limited intercession
 - No change of classes
- > Limited behavioral reflection
 - Wrappers on objects
 - No way to intercept method calls, variable access

Example: Squeak

- > Squeak 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!

Roadmap

- > Introduction: Reflection
- > **I. Sub-Method Structural Reflection**
- > II. Partial Behavioral Reflection



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

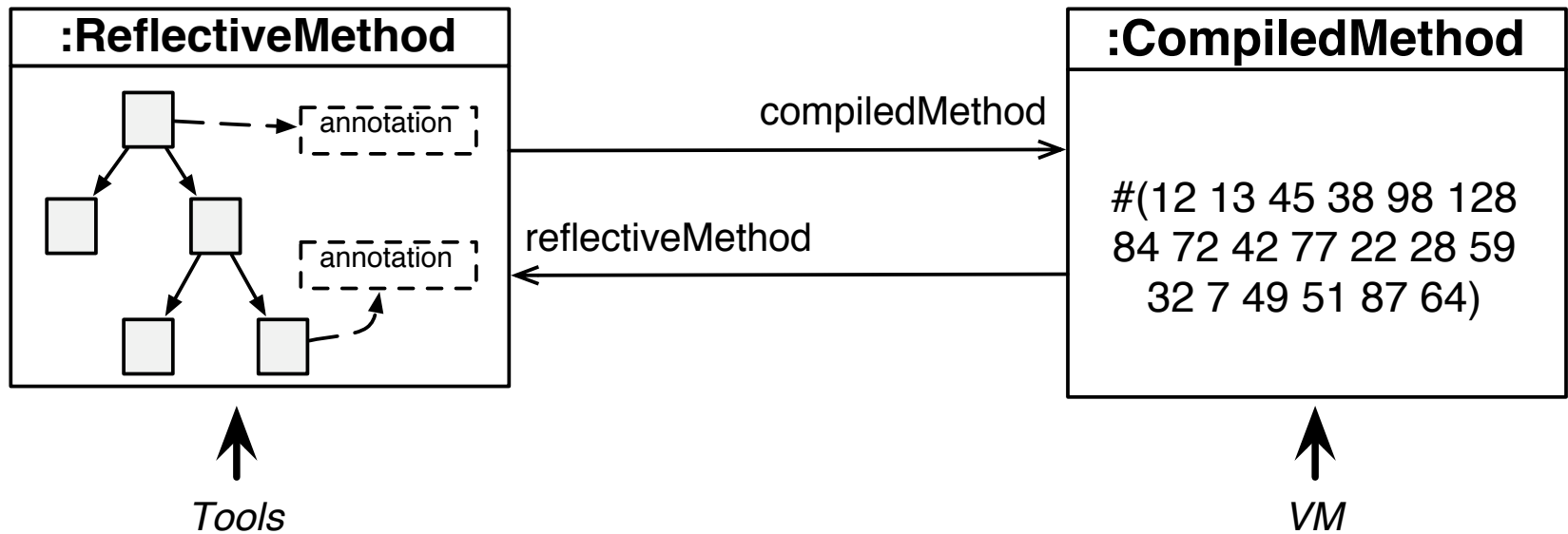
- > Low level abstraction
 - Array of Integers
- > Missing extensibility
 - e.g. for tools
- > Mix of base- and meta-level code
 - Problems with synthesized code when changing code
 - Examples: AOP point-cut residues, reflection hooks

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
- > 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 :>
```

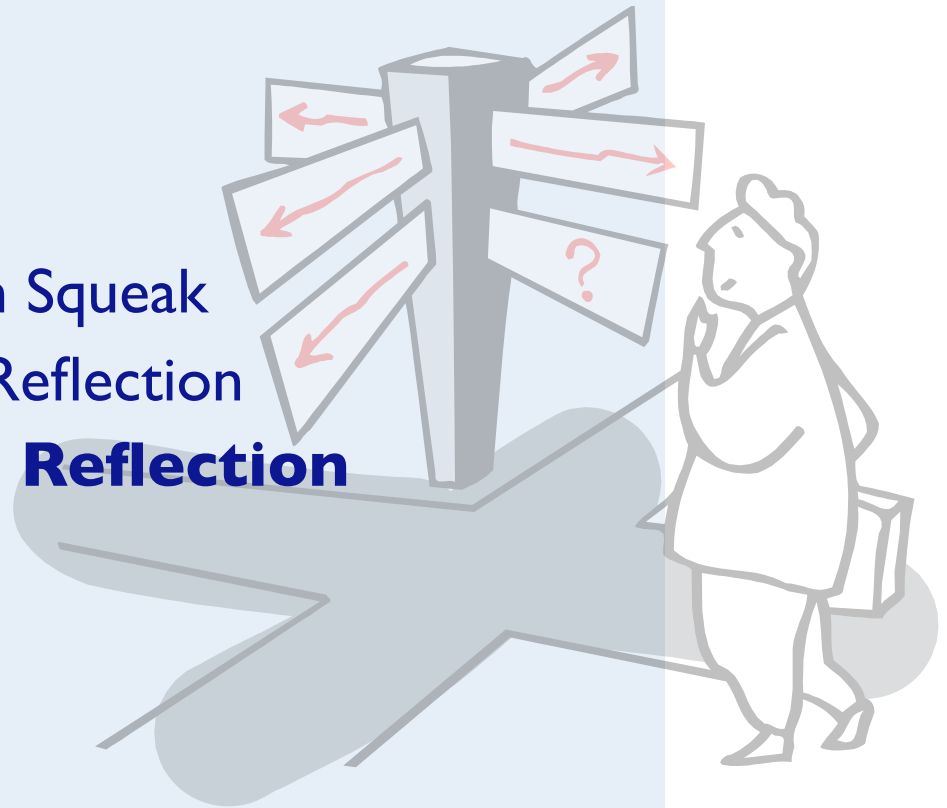
- > Optional, pluggable type-system
- > Types stored as annotations in the Reflective Methods

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

- > Introduction: Reflection in Squeak
- > I. Sub-Method Structural Reflection
- > **II. Partial Behavioral Reflection**



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!

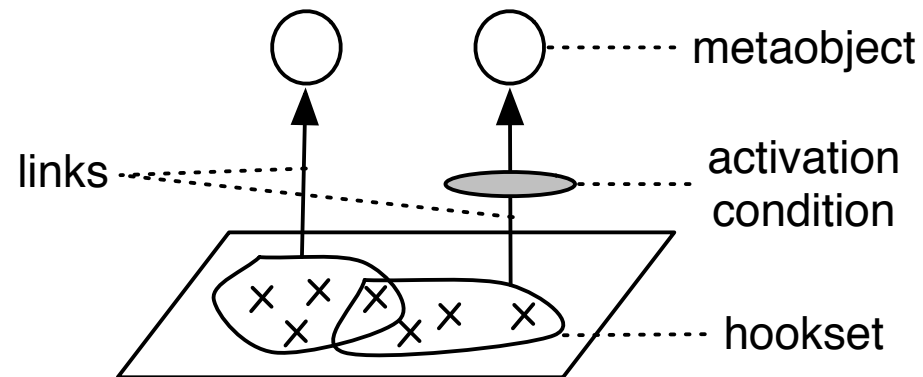
MetaclassTalk

- > 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

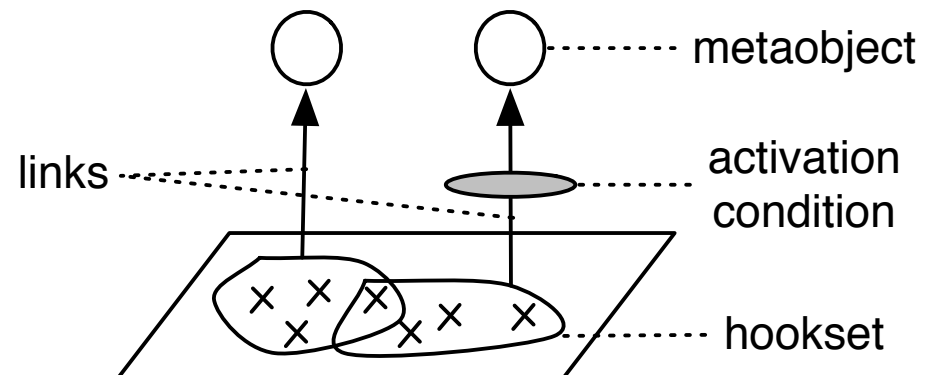
- > Goals
 - Highly selective reification
 - Flexible meta-level engineering
 - *Protocol specification*
 - *Cross-cutting hooksets*



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...)

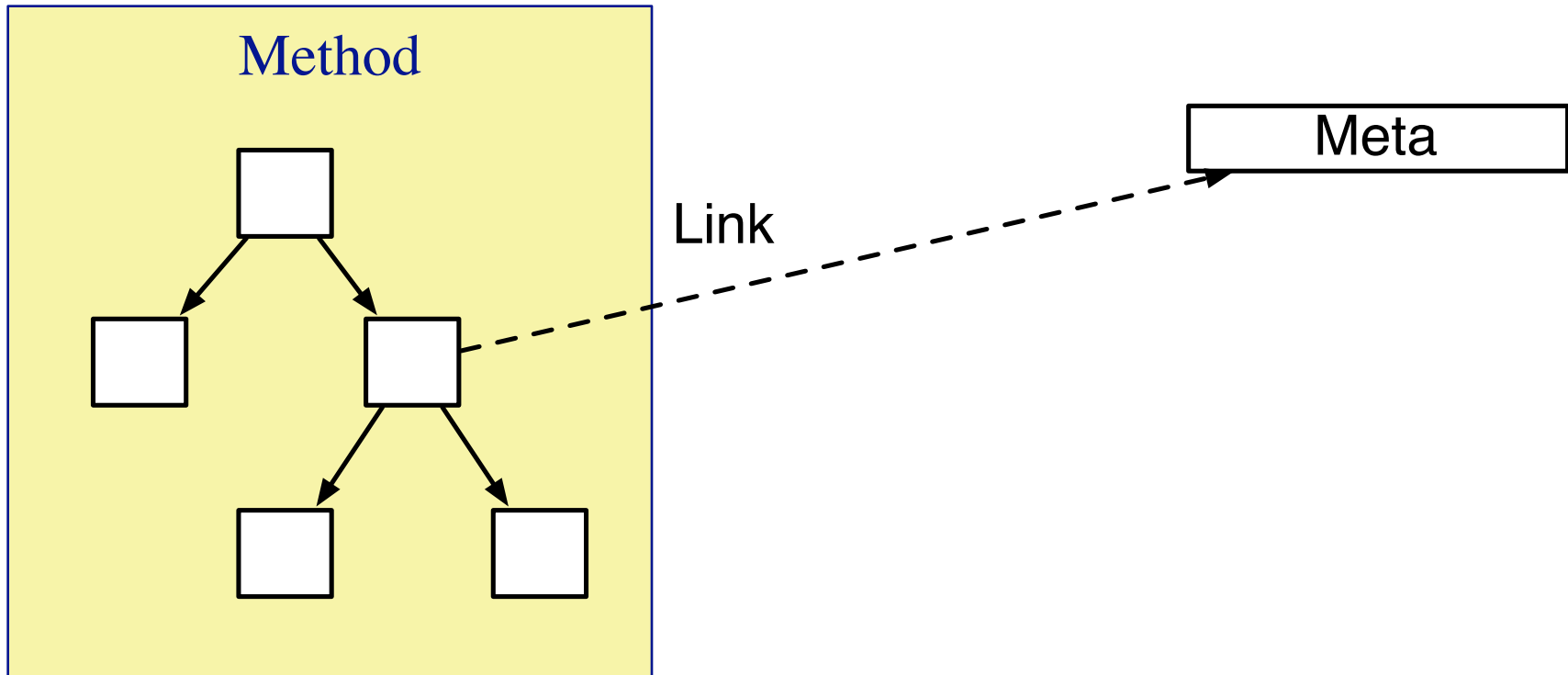
- > **Geppetto: Partial Behavioral Reflection for Smalltalk**
 - For Squeak 3.9 with Bytecode transformation

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



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>

Questions



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