

Reflection

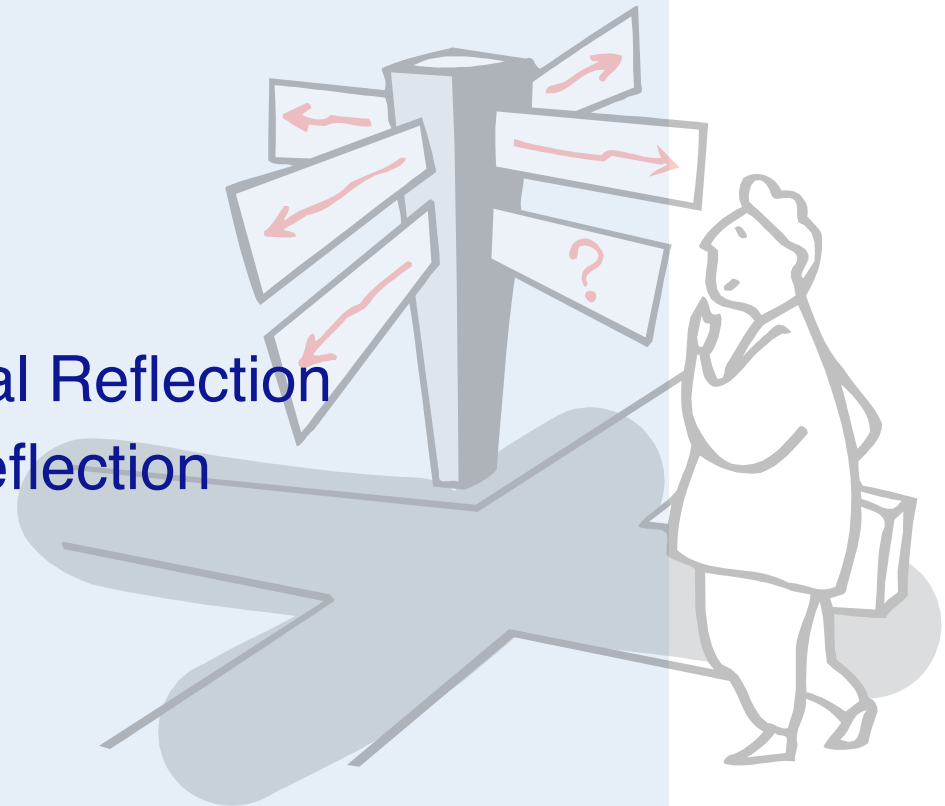
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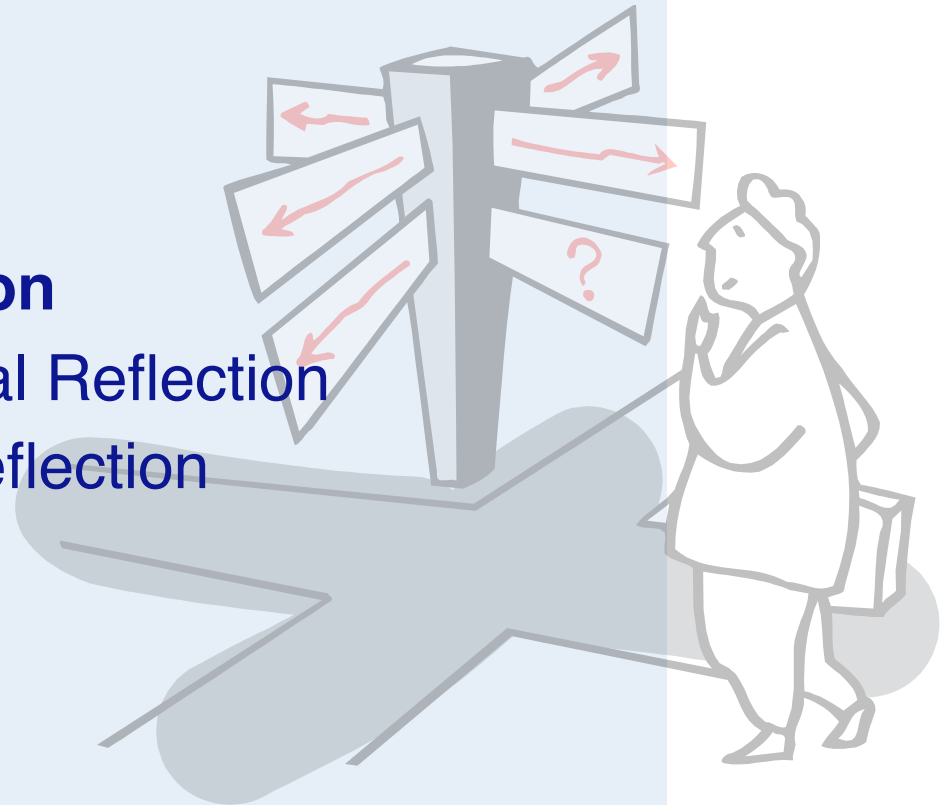
Roadmap

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



Roadmap

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



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

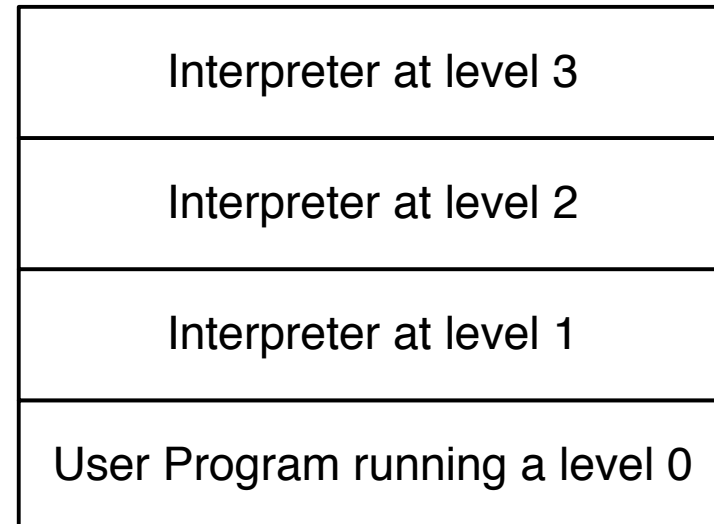
- Concerned with static structure
- For example: packages, data-types, procedures

> 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?

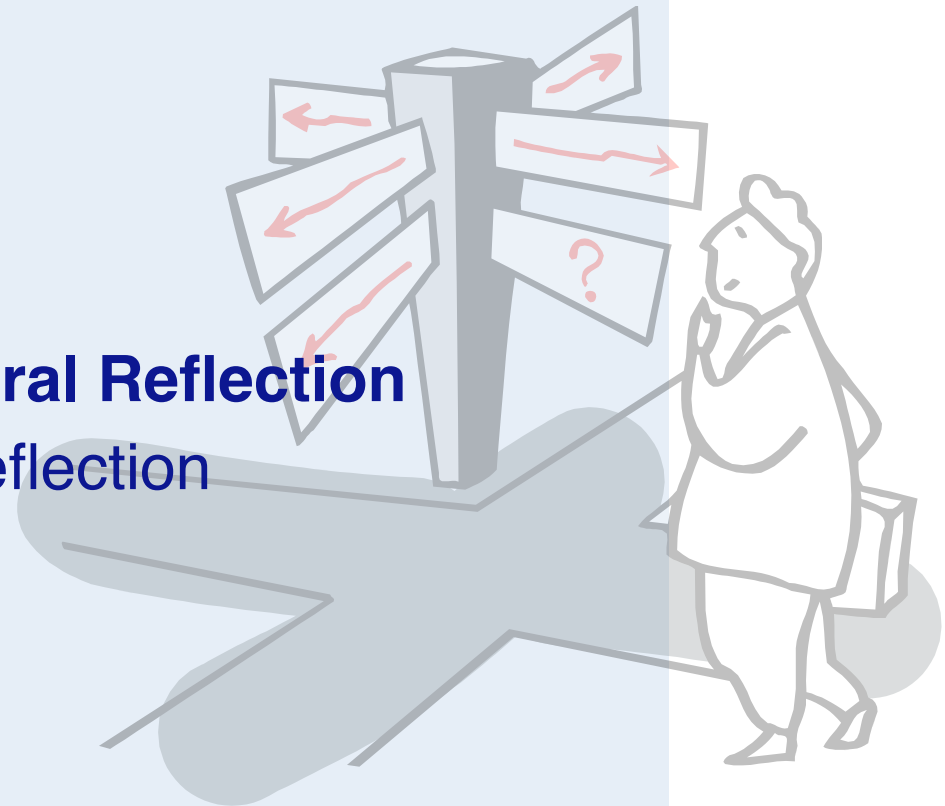
- > Structural Reflection stops at method level
 - Bytecode in the CompiledMethod: Numbers
 - Text: Just a String, needs to be compiled

- > Behavior hard coded in the Virtual Machine
 - Message Sending
 - Variable Access

- > Both structural and behavioral reflection is limited
 - We should do better!

Roadmap

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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

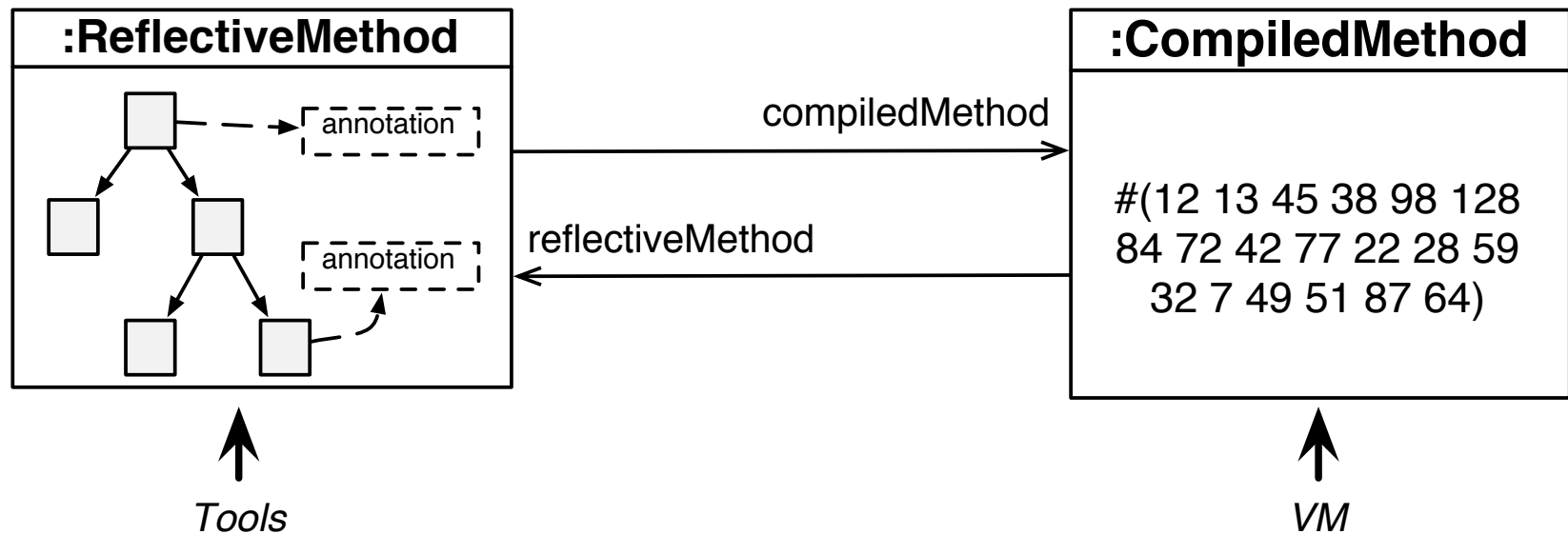
- > Mix of base- and meta-level code
 - Problems with synthesized code when changing code
 - Examples: AOP point-cut residues, reflection hooks

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 :>
```

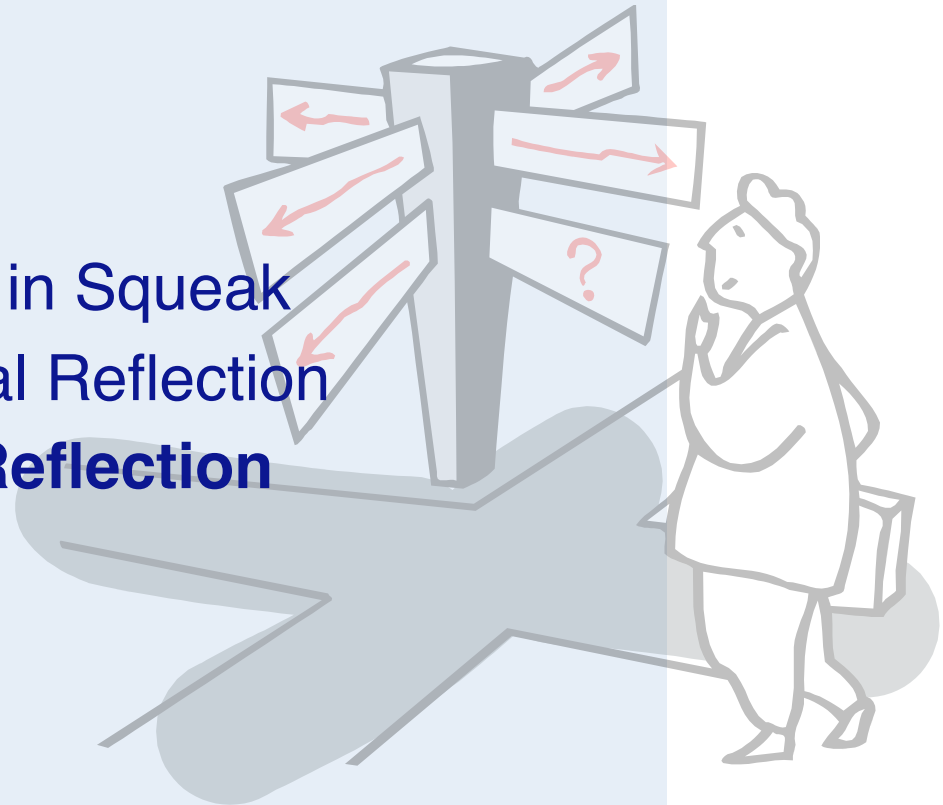
- > Optional, pluggable type-system
- > Types stored as annotations in the Reflective Methods

Memory

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

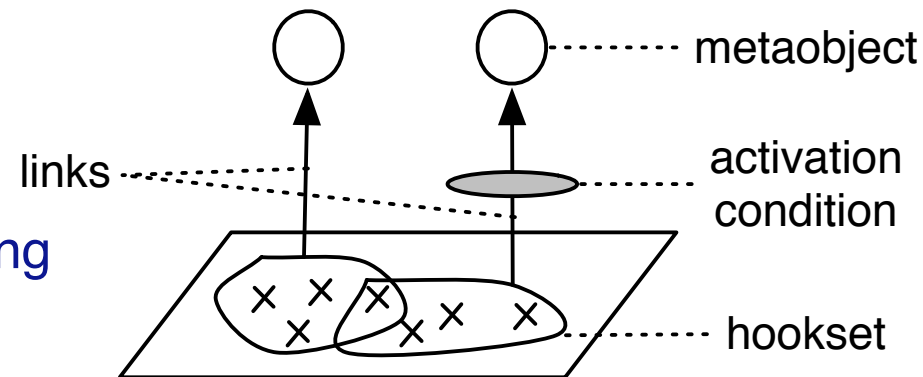
- > Metaclass defines
 - message lookup
 - access to instance variables

- > 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*



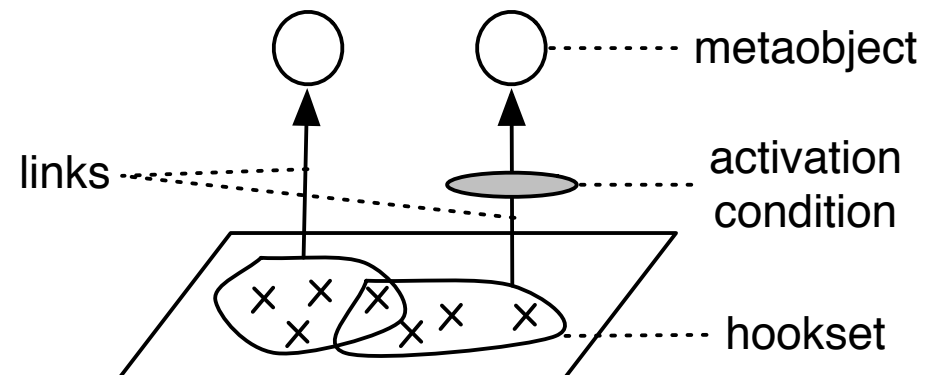
Tanter, OOPSLA03

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

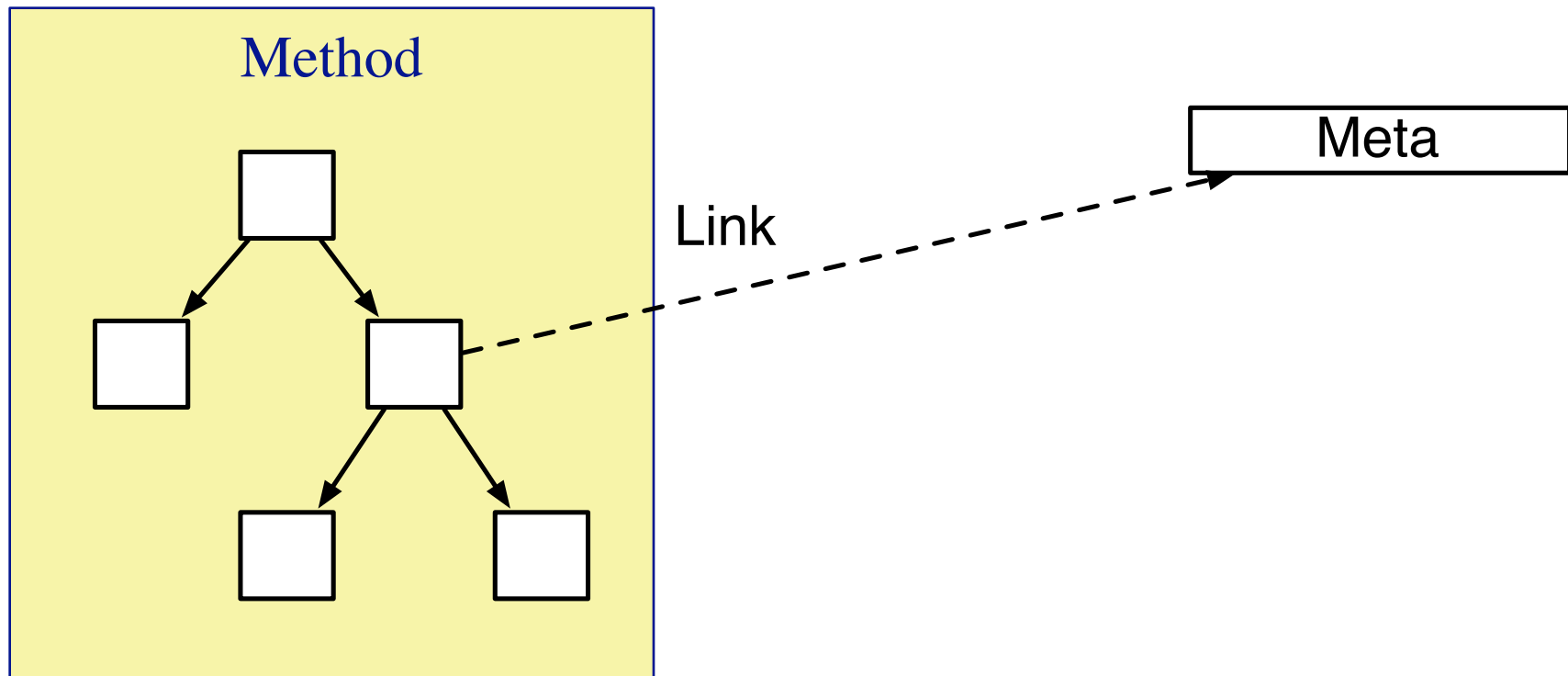
- > Annotation performance
 - Decompile bytecode

- > 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

u^b

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> Show Bounce Demo

Reflectivity

- > Prototype implementation in Squeak
 - Sub-Method Structure
 - Partial Behavioral Reflection

- > Download:

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

What's next...

- > Optimize Size of AST Representation
 - Simpler AST
 - AST Compression

- > Beyond Text
 - Store only AST (no text)
 - Build text from annotated AST

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