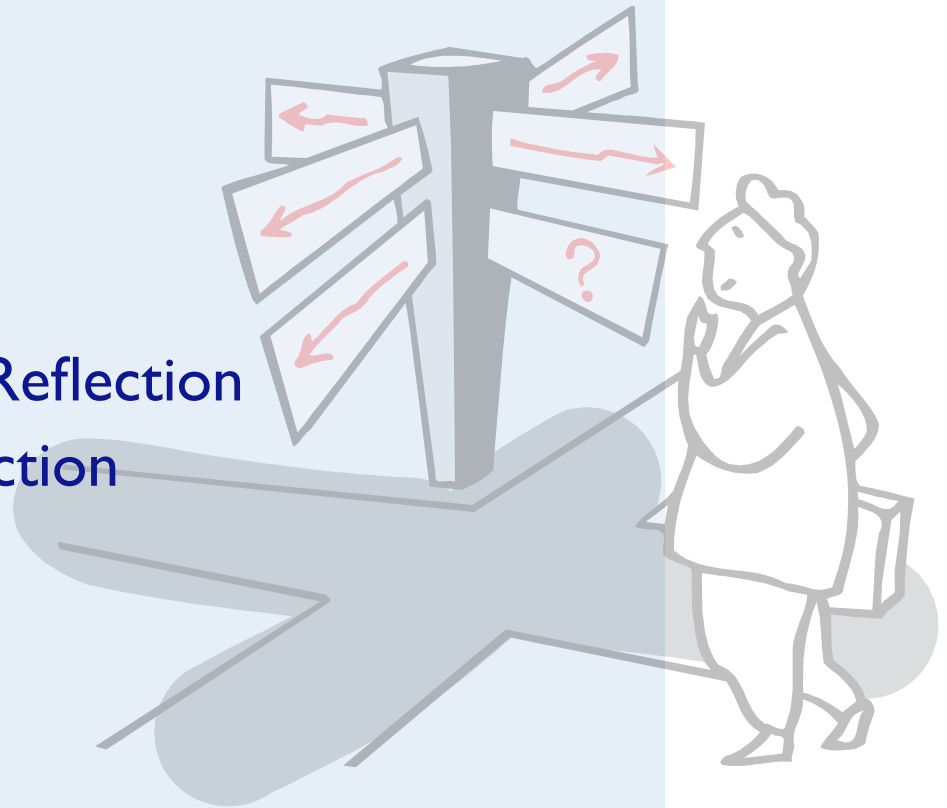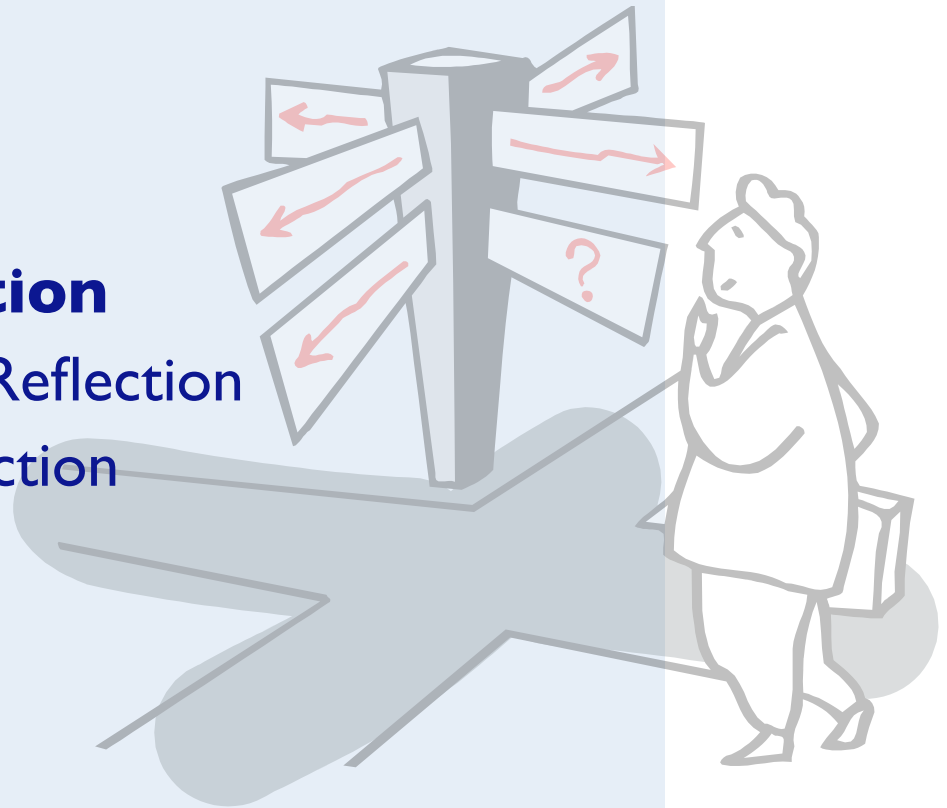# Reflection

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Roadmap

> Introduction: Reflection

> I. Sub-Method Structural Reflection

> II. Partial Behavioral Reflection
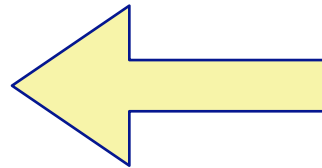
Roadmap

> **Introduction: Reflection**

> I. Sub-Method Structural Reflection

> II. Partial Behavioral Reflection

Reflection

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: 3 Lisp

> Tower of Interpreters

> Theoretical Slow!

Interpreter at level 3
Interpreter at level 2
Interpreter at level 1
User Program running a level 0
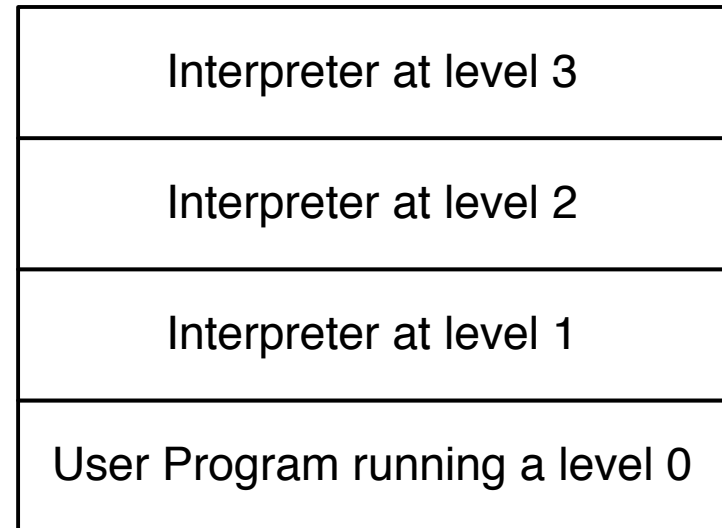
Reflection and OOP

> ## A good match: self-representation build of objects
>   — Better then 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

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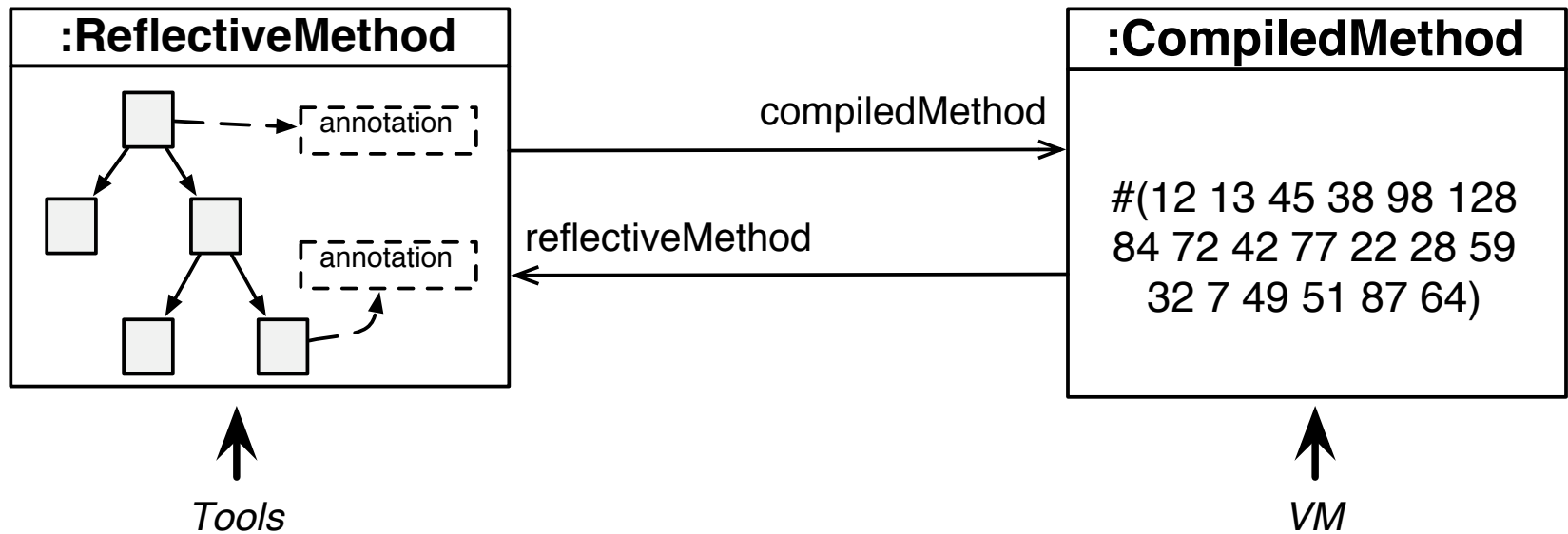
Persephone

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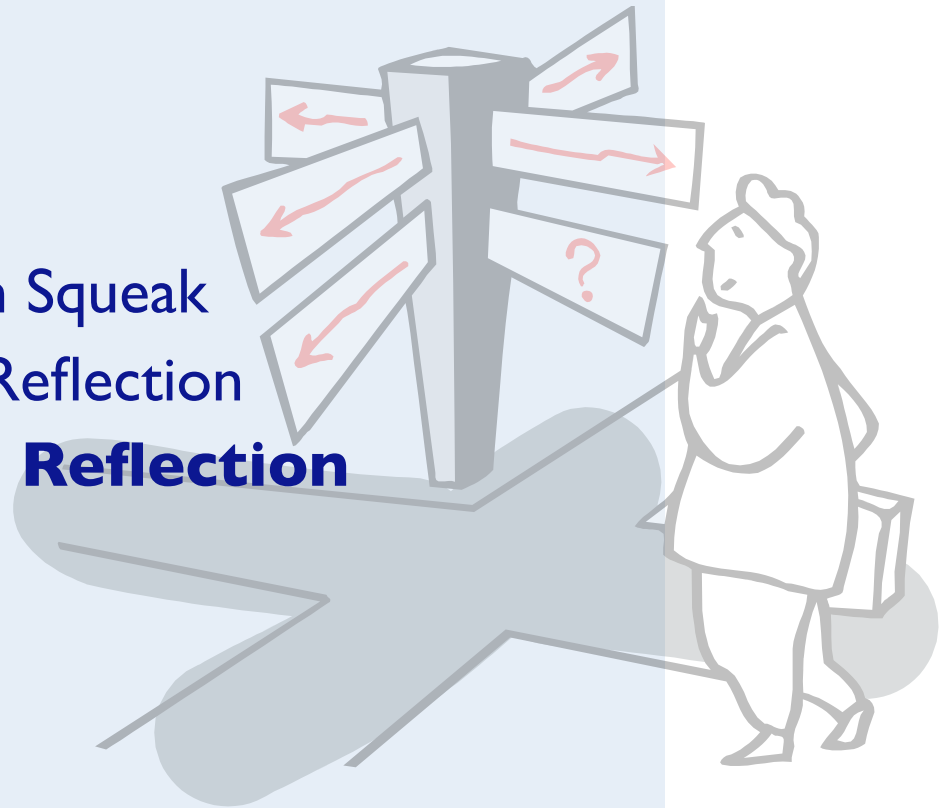
> Optional, pluggable type-system
> Types stored as annotations in the Reflective Methods

Memory

	number of classes	memory
Squeak 3.9	2040	15.7 MB
Persephone no reflective methods	2224	20 MB
Persephone reflective methods	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*
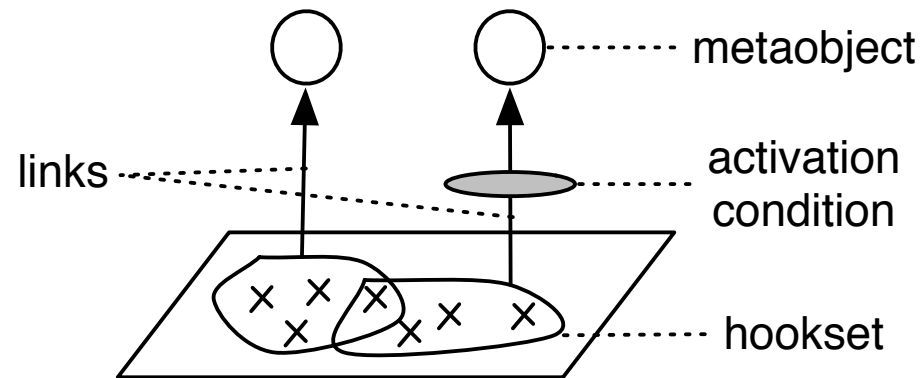
Tanter, OOPSLA03

Example: Profiler

> ## Operation:
— Method execution (around)

> ## Hookset:
— All execution operations in a package

> ## Meta-object:
— A profiling tool

metaobject

activation condition

links

hookset
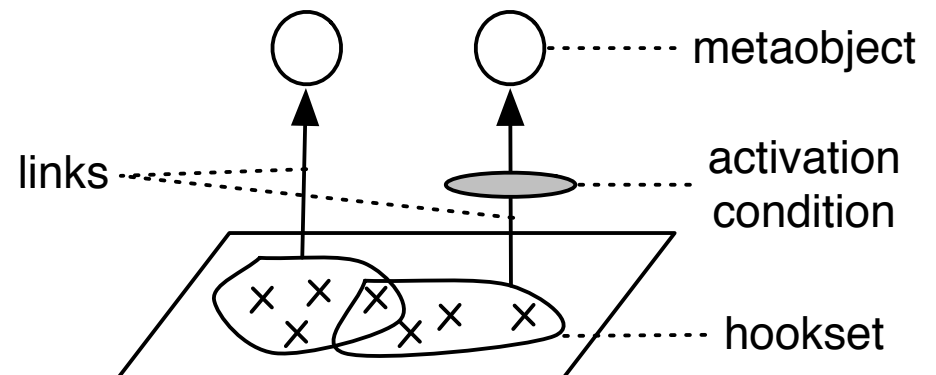
Reflex for Squeak

> 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
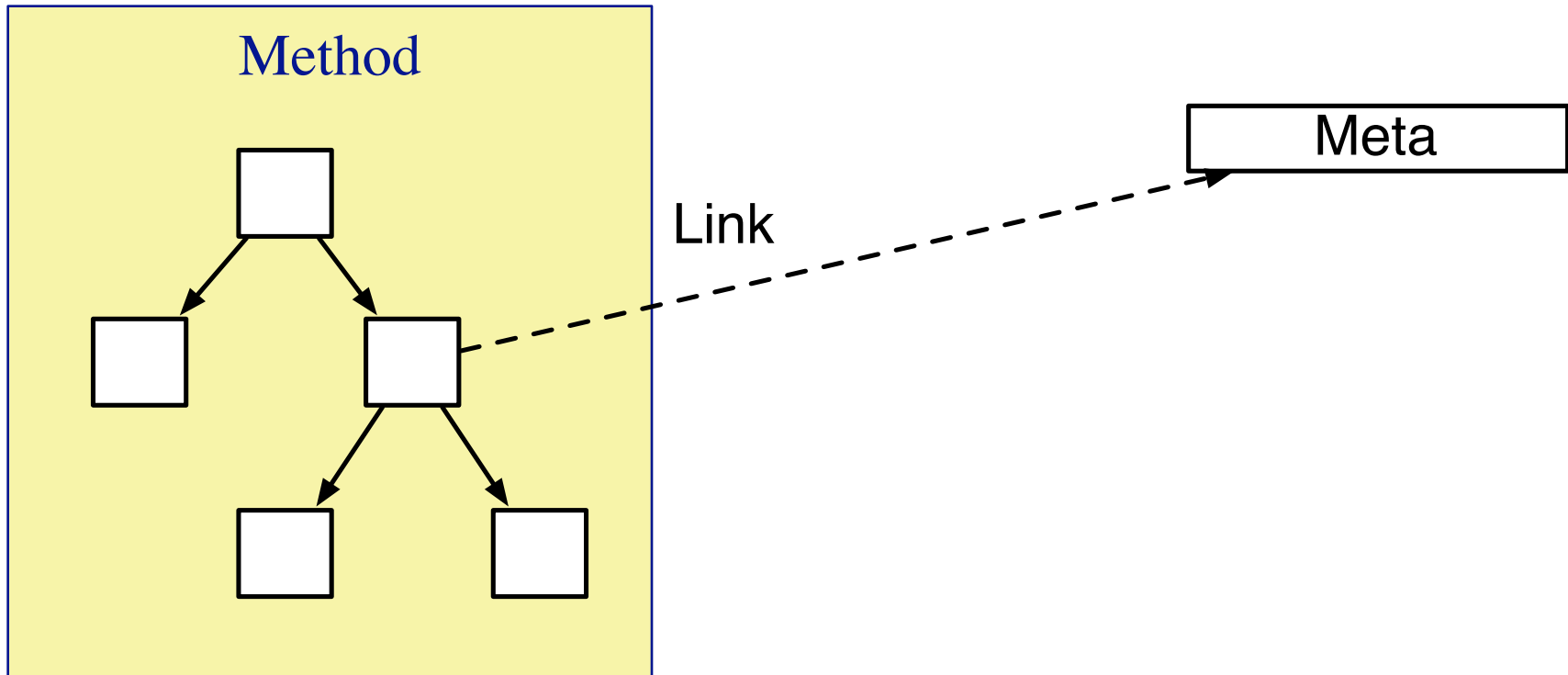
Properties

> ## 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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