Part II: Reflection

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Roadmap

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

- Introduction: Reflection in Squeak
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Reflection

> Reflection: computation about computation
  - Base level / meta level
  - Causally connected

> Structural Reflection
  - Reification of structure

> Behavioral Reflection
  - Reification of execution
Reflection in 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 in Squeak
  — We should do better!
Roadmap

- Introduction: Reflection in Squeak
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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
> **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

> 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
From the last lecture...

Tools
- Refactoring
- Code Editing
- Version Control
- Presentation
- Compilation

Model
- Structure
  - #isSelfSend
  - #isTemp
  - #isRead
  - ...
- Behavior
  - #isSelfSend
  - #isTemp
  - #isRead
  - ...
- Extensions
  - data
  - behavior

External
- Text
- Bytecode
- ...

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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

<table>
<thead>
<tr>
<th></th>
<th>number of classes</th>
<th>memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squeak 3.9</td>
<td>2040</td>
<td>15.7 MB</td>
</tr>
<tr>
<td>Persephone</td>
<td>2224</td>
<td>20 MB</td>
</tr>
<tr>
<td>no reflective methods</td>
<td>2224</td>
<td>123 MB</td>
</tr>
<tr>
<td>Persephone</td>
<td>2224</td>
<td>123 MB</td>
</tr>
<tr>
<td>reflective methods</td>
<td>2224</td>
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</tbody>
</table>
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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 metaobjects
  – Define Protocol between base and meta

> Goals
  – Highly selective reification
  – Flexible metalevel engineering
    – *Protocol specification*
    – *Cross-cutting hooksets*

Tanter, OOPSLA03
Example: Profiler

- **Operation:**
  - Method Execution (around)

- **Hookset:**
  - All execution operations in a package

- **Metaobject:**
  - A profiling tool
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
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

> Implement Context Oriented Programming (COP)
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