Advanced Reflection: MetaLinks

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What we know…

- Smalltalk is reflective
- Classes, Methods, Stack-Frames… are Objects
- Reflective API on all Objects

Take home message

- Reflection is based on the meta-class model, thus inherently structural.

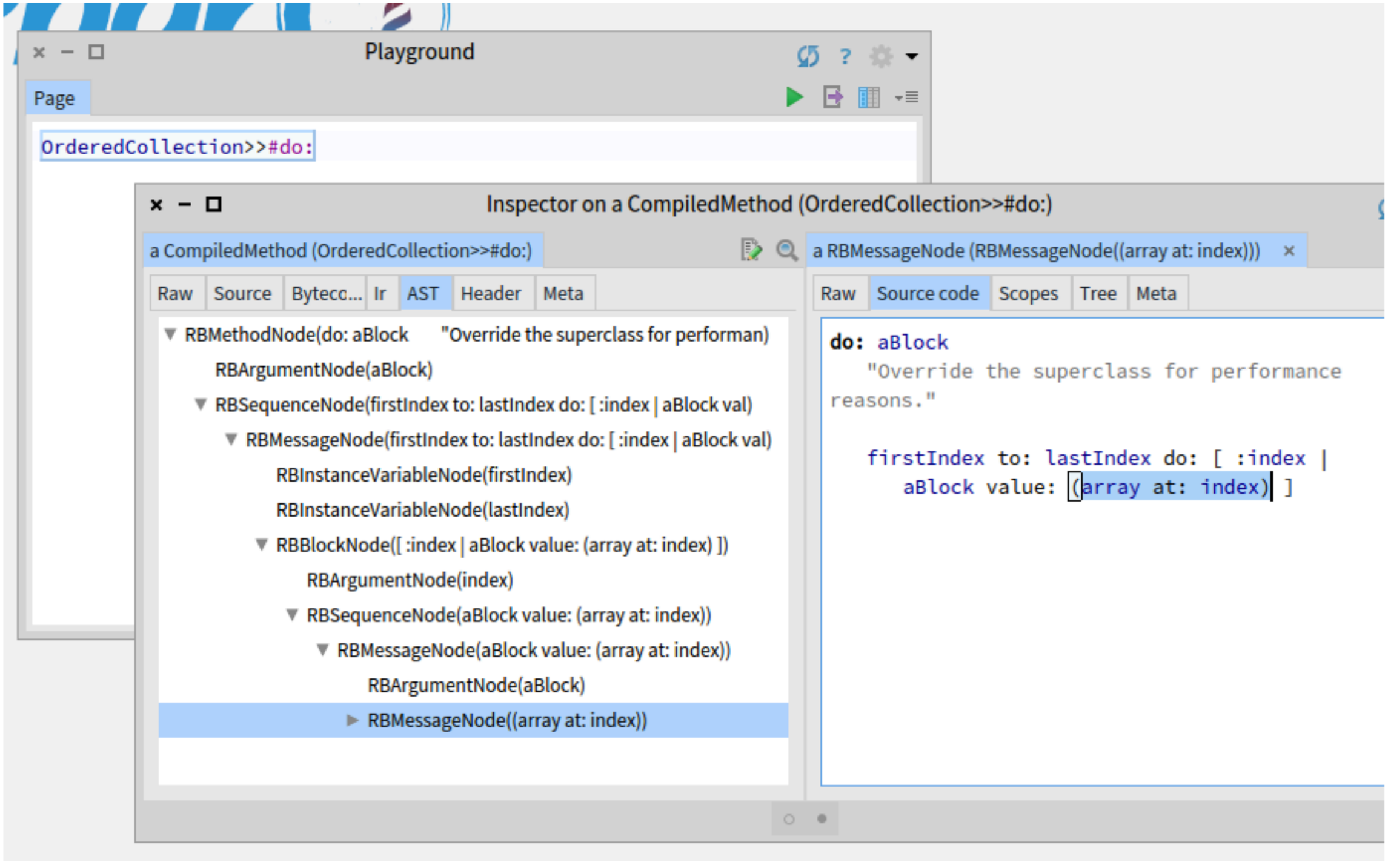
- Behavioural reflection limited to:
  - Method lookup upon failure (`doesNotUnderstand`: message)
  - Current execution reified (`thisContext`)

Can we do better?

- A more fine-grained reflective mechanism seems to be missing

- Let’s look again at a Method in the Inspector

Inspector on a Method



The AST

- AST = **A**bstract **S**yntax **T**ree
- Tree Representation of the Method
- Produced by the Parser (part of the Compiler)
- Used by all tools (refactoring, syntax-highlighting,…)

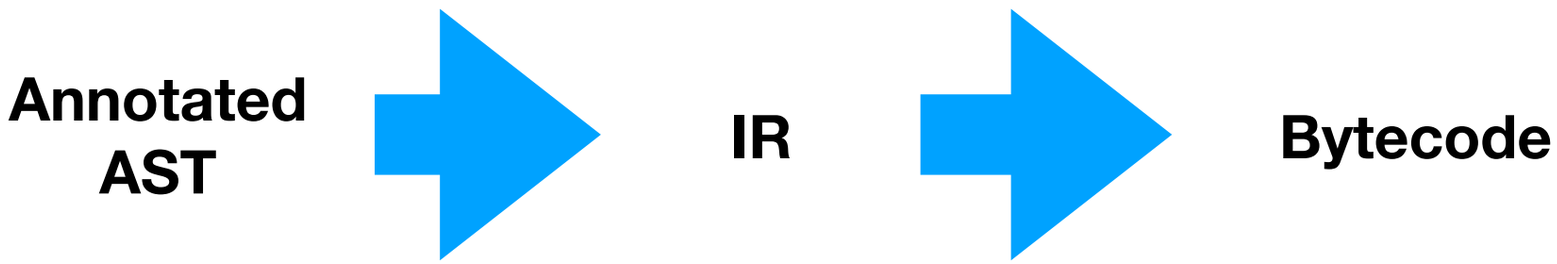
```
Smalltalk compiler parse: 'test ^(1+2)'
```

The Compiler

- `Smalltalk compiler` -> Compiler Facade
- Classes define the compiler to use
    - You can override method #compiler
- Behind: Compiler Chain

The Compiler

`RBParser` `OCSemanticAnalyzer`



`OCASTTranslator/ IRBuilder` `IRBytecodeGenerator`

AST

- RBMethodNode — Root
- RBVariableNode — Variable (read and write)
- RBAssignmentNode — Assignment
- RBMessageNode — A Message (most of them)
- RBReturnNode — Return

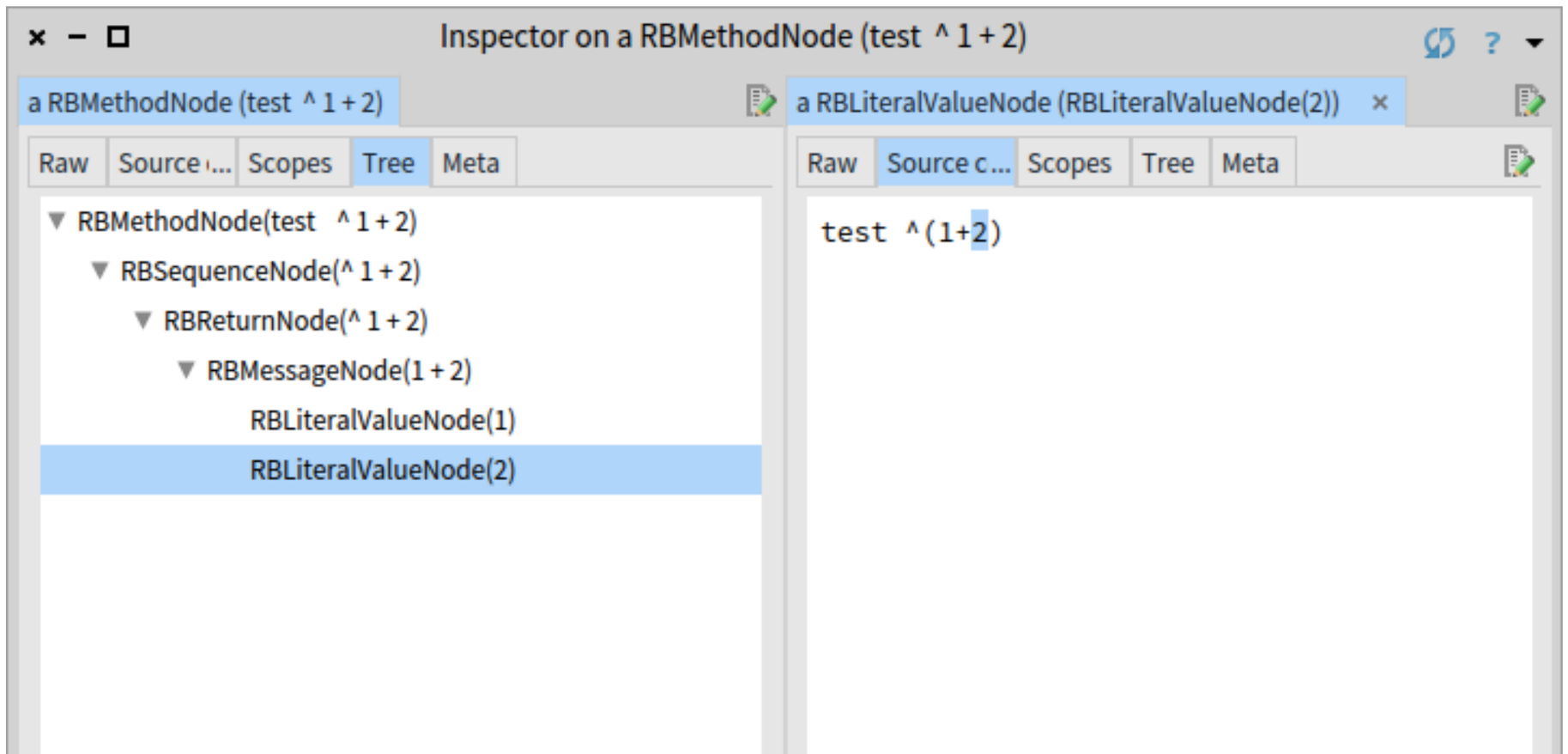
AST: Navigation

- To make it easy to find and enumerate nodes, there are some helper methods
- CompiledMethod has: `#sendNodes, #variableNodes, #assignmentNodes`
- Every AST node has `#nodesDo:` and `#allChildren`

Inspect a simple AST

- A very simple Example

```
Smalltalk compiler parse: 'test ^(1+2)'
```



Integration

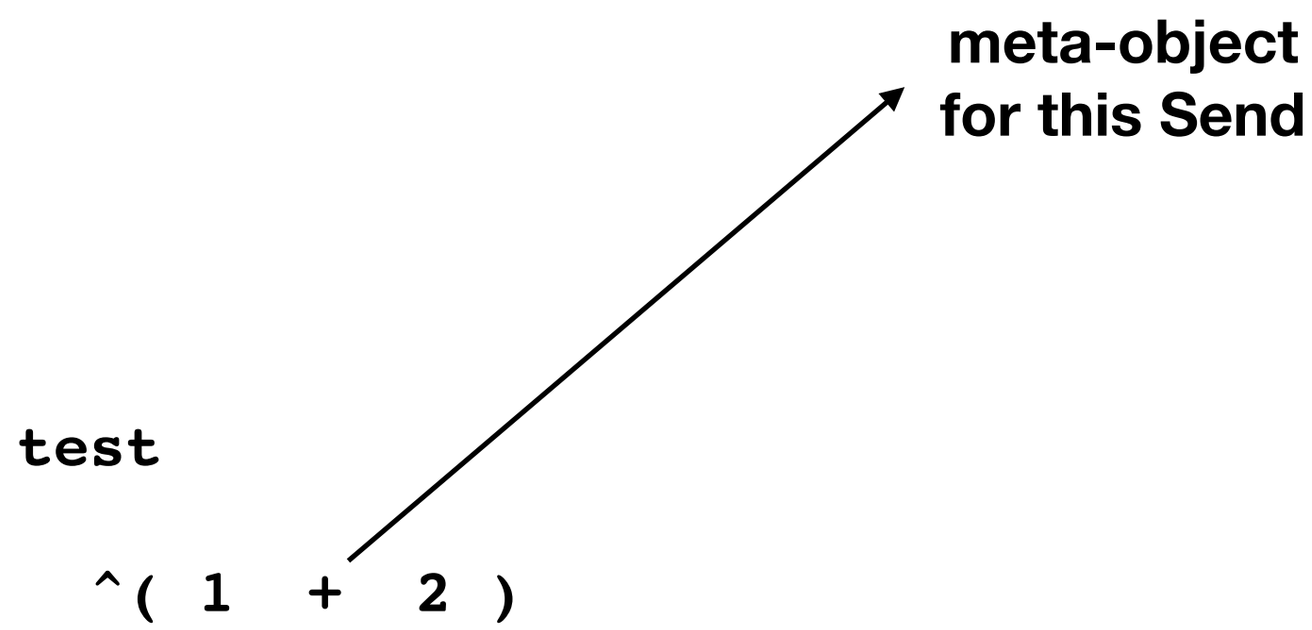
- Originally just internal to the compiler
- Pharo:
  - send #ast to a method to get the AST
  - Cached for persistency.

(Point>>#x) ast == (Point>>#x) ast
—> true

Wouldn’t it be nice..

- With the AST, wouldn’t it be nice if we could use this structure for Behavioural Reflection?

- If we could somehow attach a “arrow to the code” that points to a meta-object



We have all pieces…

- We have the AST for each method
- It is quite simple
- We have a compiler in the system
- So this should be possible…

The MetaLink

```
link := MetaLink new
      metaObject: Halt;
      selector: #once;
      control: #before.
```

- MetaLink points to metaObject
- Defines a selector to call
- And a control attribute: #before, #after, #instead
- Installed on a AST node:

```
(Number>>#sin) ast link: link
```

The MetaLink

- Can be installed on any AST Node
- Methods will be re-compiled on the fly just before next execution
    - Link installation is very fast
- Changing a method removes all links from this method
    - Managing link re-installation has to be done by the user

MetaLink: MetaObject

- MetaObject can be any object
- Even a Block: `[Transcript show ‘hello’]`
- Install on any Node with #link:
- de-install a link with #uninstall

MetaLink: Selector

- MetaLink defines a message send to the MetaObject
- #selector defines which one
- Default is #value
- Yes, a selector with arguments is supported
  - We can pass information to the meta-object

MetaLink: Argument

- The arguments define which arguments to pass

- We support a number of **reifications**

Reifications

- Reifications define data to be passed as arguments
- Reify —> Make something into an object that is not one normally
- Example: “All arguments of this message”

Reifications: examples

- All nodes: `#object #context #class #node #link`
- Sends: `#arguments #receiver #selector`
- Method: `#arguments #selector`
- Variable: `#value`

They are defined as subclasses of class RFReification

Reifications as MetaObject

- We support some special metaObjects:
  - #node The AST Node we are installed on
  - #object `self` at runtime
  - #class The class the links is installed in

MetaLink: Condition

- We can specify a condition for the MetaLink
- Link is active if the condition evaluates to true
- We can pass reifications as arguments

```
link := MetaLink new
     metaObject: Halt;
     selector: #once;
     condition: [:object | object == 5] arguments: #(object).

(Number>>#sin) ast link: link.
```

MetaLink: control

- We can specify when to call the meta-object
- We support `#before, #after` and `#instead`
- The instead is very simple: last one wins

Example: Log

- We want to just print something to the Transcript

```
link := MetaLink new
    metaObject: [Transcript show: 'Reached Here'].

(Number>>#sin) ast link: link
```

Recursion Problem

- Before we see more examples: There is a problem
- Imagine we put a MetaLink on some method deep in the System (e.g `new, +, do:`).
- Our Meta-Object might use exactly that method, too

Endless Loop!!

Recursion Problem

- Solution: Meta-Level
- We encode the a level in the execution of the system
- Every Link Activation increases the level
- A meta-link is just active for one level. (e.g. 0)

```
link := MetaLink new
   metaObject: [ Object new ];
   level: 0.

(Behavior>>#new) ast link: link.
```

Example: Log

- Better use #level: 0

- Nevertheless: be careful! If you add this to method called often it can be very slow.

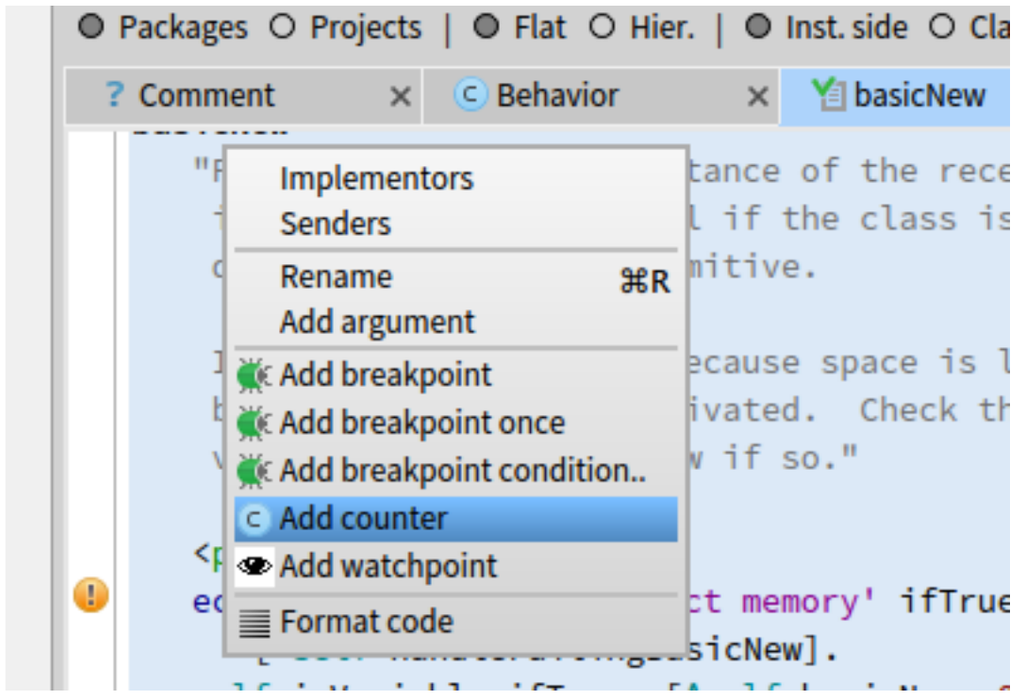
```
link := MetaLink new
    metaObject: [Transcript show: 'Reached Here'];
    level: 0.
```

Example: Counter

- In the Browser you can add a “counter” to the AST
- See class `ExecutionCounter`

```
install

    link := MetaLink new
                metaObject: self;
                selector: #increase.
    node link: link.
```



Example: Breakpoint

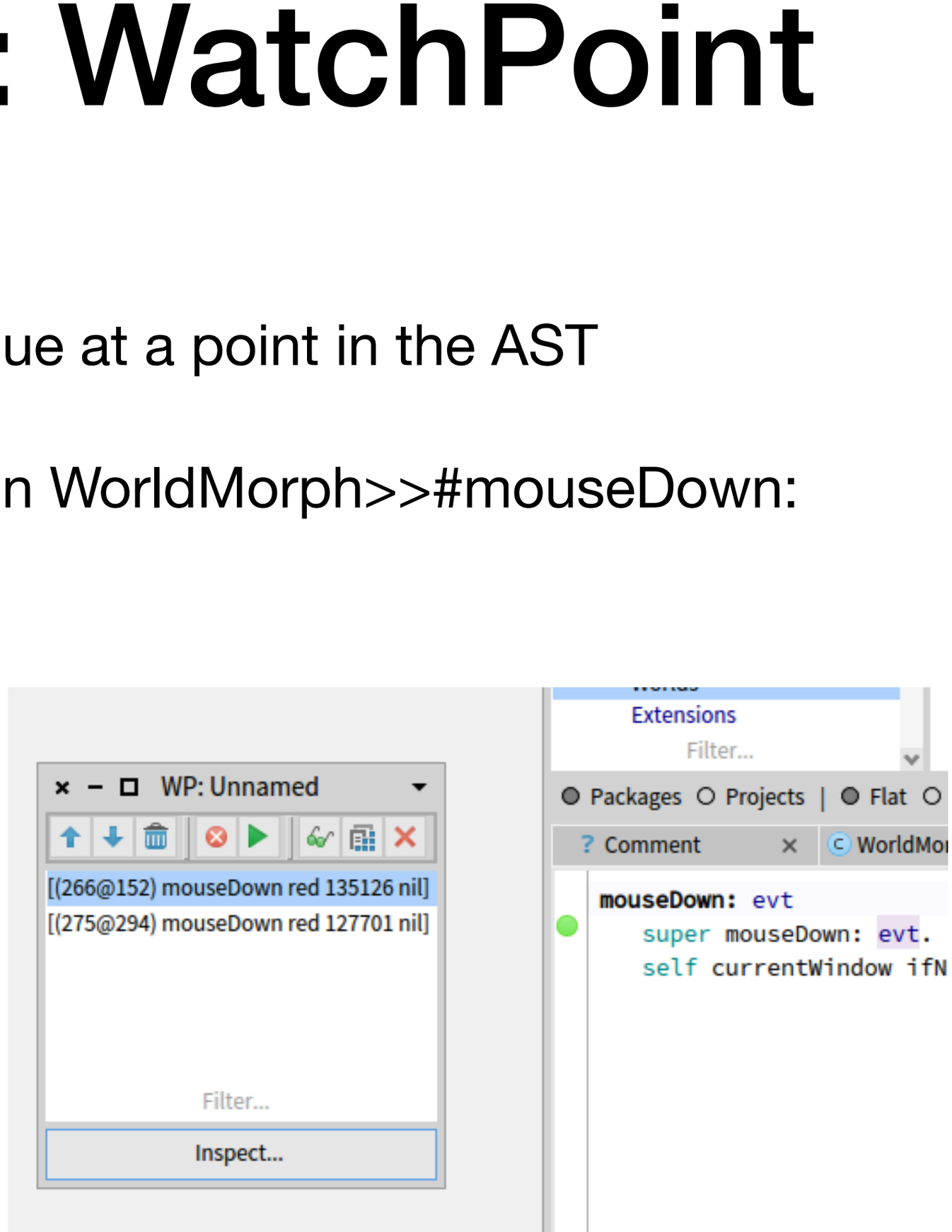
- "*Add Breakpoint*" in AST (Suggestions) Menu
- See class Breakpoint
- Break Once
- Conditional Break

```
breakLink
   ^ MetaLink new
         metaObject: Break;
         selector: #break;
         options: options
```

Example: WatchPoint

- Watchpoint: Record Value at a point in the AST
- Example: Watch event in WorldMorph>>#mouseDown:

Click on background
-> value recorded



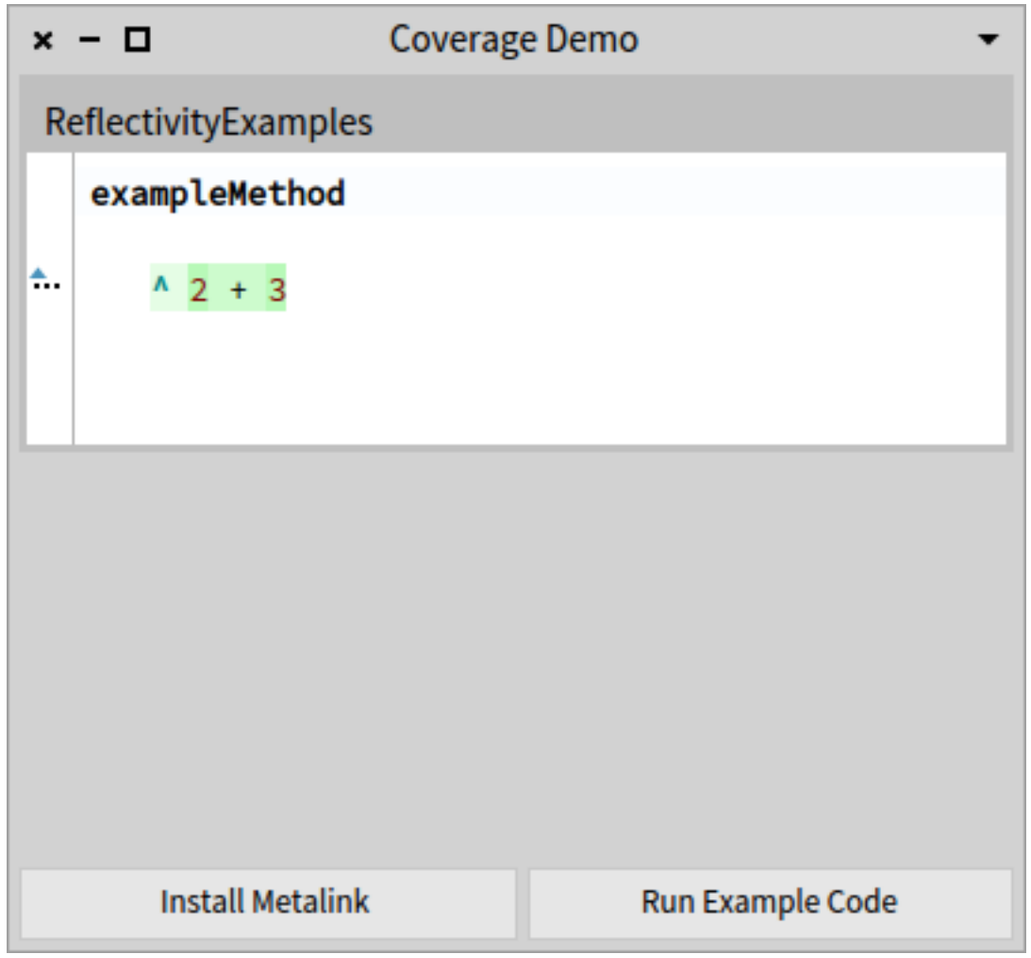
Example: WatchPoint

- Implementation: class `Watchpoint`, method `install`
- example of a #after link with a condition

```
link := MetaLink new
            metaObject: self;
            selector: #addValue:;
            arguments: #(value);
            control: #after;
            condition: [ recording ].
```

Example: Code Coverage

- Small Demo.
- Start with `CoverageDemo new openWithSpec`



Example: Code Coverage

- Example of a MetaLink with a #node MetObject
- Meta-Object is the node that the link is installed on

```
link := MetaLink new
      metaObject: #node;
      selector: #tagExecuted.
```

Interesting Properties

- Cross Cutting
  - One Link can be installed multiple times
    - Over multiple methods and even Classes
    - And across operations (e.g., Send and Assignment) as long as all reifications requested are compatible
- Fully Dynamic: Links can be added and removed at runtime
- Even by the meta-object of another meta-link!

Limitations

- Better use Pharo7 (we are improving it still)
- Still some bugs with #after on MethodNode
- Loops: next execution of a method. Need to restart long running loops (no on-stack replacement).
- Keep in mind: next metaLink taken into account for next method activation
    - Take care with long running loops!

Help Wanted

- We are always interested in improvements!
- Pharo7 is under active development.
- Pull Requests Welcome!