

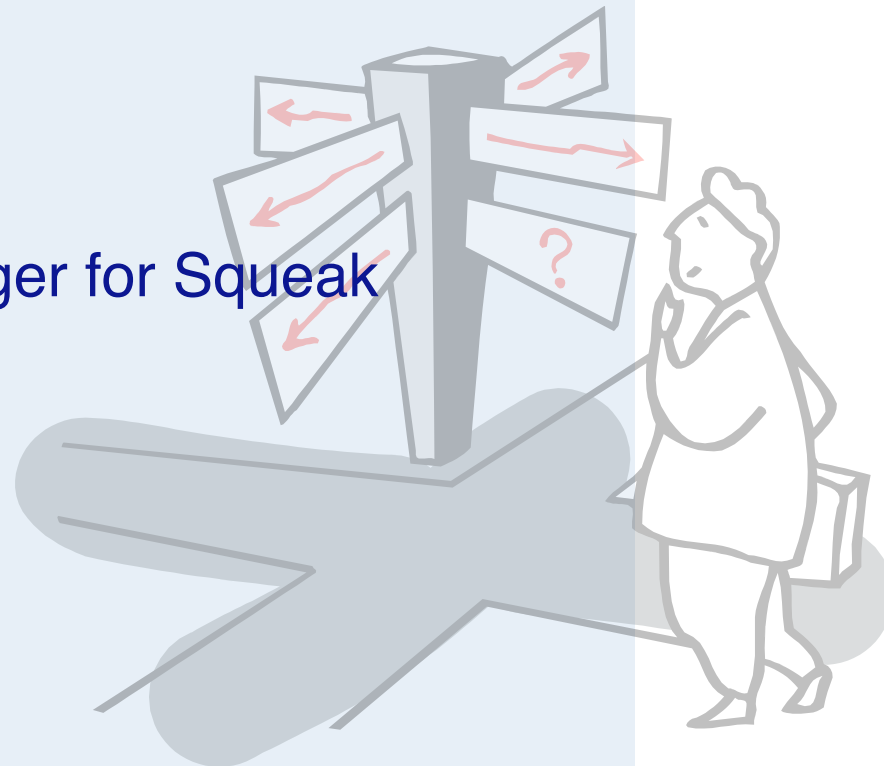
Design and Implementation of a Backward-In-Time Debugger

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Roadmap

- > Problem
- > Unstuck: A new Debugger for Squeak
- > Implementation
- > Lessons Learned
- > Future work



Problem

- > Debugger: Snapshot of state at time of error
- > Cause for errors is in the past
 - Who assigned *that* value?
- > very incomplete history available
 - guess were to set breakpoint, rerun

Example

```
Foo>>initialize
  var1 := 0.
  var2 := ''.
```

```
Foo>>start
  self beforeBar.
  self bar.
  self moreBar.
```

```
Foo>>beforeBar
  var1 = 0 ifTrue: [
    var2 := nil.]
```

```
Foo>>bar
```

```
.....
```

```
Foo>>moreBar
```

```
  var2 size > 0 ifTrue:[
    ^var2 at: 1].
  ^''
```

Stack Trace

- > Squeak Debugger
- > Shows stack trace
 - methods not returned
 - old state lost

```
× Error: Instances of UndefinedObject
UndefinedObject(Object)>>error:
UndefinedObject(Object)>>errorNotIndexable
UndefinedObject(Object)>>size
Foo>>moreBar
Foo>>start
Foo class>>start
UndefinedObject>>Foo
UndefinedObject(Object)>>executeMethod:
...

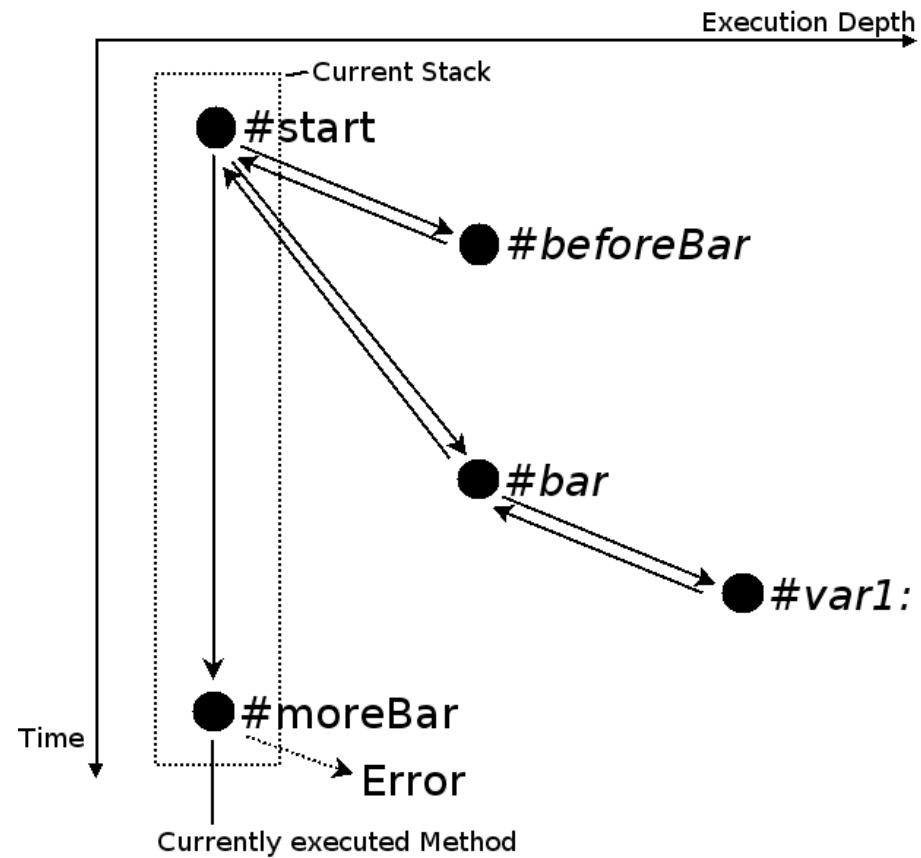
Proceed Restart Into 0

moreBar
var2 size > 0 ifTrue: [
  ↑var2 at: 1
].
↑

self
all inst vars
var1
var2 nil
```

Stack Trace

- > Squeak Debugger
- > Shows stack trace
 - methods not returned
 - old state lost



Methods in italic means their execution is finished

Solution



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- > We want:
 - Record the history of the program
 - View the state at any point in the past

- > Unstuck
 - A new Debugger for Squeak
 - Provides full trace information

Unstuck UI

1. Trace
2. Object
3. Code
4. History
5. Query

TraceDebugger

highlighted events: first next previous last

```

#startMethod
  JRecompiler class#new -> a JRecompiler
  a JRecompiler#recompile:in:(#exampleInstVar, JExamples class)
    JExamples class#compiledMethodAt:(#exampleInstVar) -> a J
    JExamples class#sourceCodeAt:(#exampleInstVar) -> a Text
    a JImmediateMethod#getSourceFor:in:(#exampleInstVar, JE
    a JImmediateMethod#compiledMethod -> a CompiledMeth
    a CompiledMethod (3707)#==(nil)
    a CompiledMethod (3707)#getSourceFor:in:(#exampleInst
    RBMethodNode class#new -> RBMethodNode class
    RBMethodNode class#basicNew -> a RBMethodNode
    a RBMethodNode#selectorParts:arguments:(an Array({e
    a RBMethodNode#arguments:(#())
    #()#do:({() in RBMethodNode>>arguments: )
    a RBMethodNode#comments:(an OrderedCollection("["
    a RBMethodNode#methodPatternStop -> a RBMethodN
    a RBMethodNode#arguments -> #()
    #()#isEmpty -> true
    a RBMethodNode#selectorParts -> an Array({exampl
    an Array({exampleInstVar(1,14,#(22))})#first -> {ex
    {exampleInstVar(1,14,#(22))})#stop -> 14
    a RBMethodNode#selector -> a RBMethodNode
    nil#isNil -> true
    a RBMethodNode#buildSelector -> #exampleInstVar
    String class#new:(50)
    WriteStream class#on:('')
    an Array({exampleInstVar(1,14,#(22))})#do:({() in R
    {exampleInstVar(1,14,#(22))})#value -> 'example
  
```

return value of: #new
received message: #recompile:in:
passed as argument: 3
passed as argument: 4
assigned to instvar: requestor

recompile: selector in: class
"Recompile method in class. If method can't be recompiled (because of compile error) add it to problemMethods with general reason"
[source oldMethod trailer methodNode newMethod |
oldMethod _ class compiledMethodAt: selector.
"oldMethod isClosureCompiled ifTrue: [^ self]."
source _ class sourceCodeAt: selector.
source ifNil: [^ self problem: 'no source' sel: selector in: class].
trailer _ oldMethod trailer.
methodNode _ JCompiler new
compile: source in: class notifying: self
ifFail: [^ self problem: 'syntax error' sel: selector in: class].
selector == methodNode selector iffFalse: [
^ self problem: 'selector changed' sel: selector in: class].
newMethod _ methodNode generate: trailer.

event isSend &
event receiver class = CompiledMethod

Search result: 11 events found

Searching



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Variable	Search Domain
event	All events
send	all message sends
return	all method returns
varAccess	all variable accesses
instVarAccess	instance variable access
tempVarAccess	temporary variables

Searching: Example

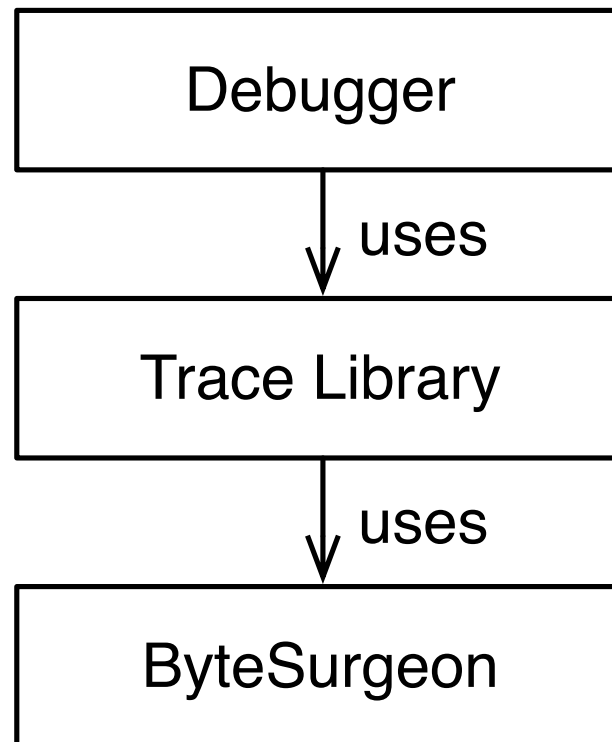
Query	Result
send selector = #foo	All the executed methods named "foo"
return returnValue > 4	All returns with a return value greater than 4
events isSend & (even arguments size = 1)	Message sends with exactly one argument

Coloring

- > We can assign a color to any object
- > Easy tracking of objects
- > Color is shown in all views of the UI

```
RBMethodNode class#basicNew -> a RBMethodNode
a RBMethodNode#selectorParts:arguments:(an Array)
a RBMethodNode#arguments:(#())
#()#do:([], in RBMethodNode>>arguments: )
a RBMethodNode#comments:(an OrderedCollection)
a RBMethodNode#methodPatternStop -> a RBMethodNode
a RBMethodNode#arguments -> #()
#()#isEmpty -> true
a RBMethodNode#selectorParts -> an Array({exampleInstVar(1,14,#(22))}
an Array({exampleInstVar(1,14,#(22))})#first ->
{exampleInstVar(1,14,#(22))}#stop -> 14
a RBMethodNode#selector -> a RBMethodNode
nil#isNil -> true
a RBMethodNode#buildSelector -> #exampleInstVar(1,14,#(22))
String class#new:(50)
```

Implementation



ByteSurgeon



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- > Framework for editing bytecode for Squeak
 - Like Javasist in Java, but:
- > Uses structural reflection to transform at runtime
 - Simple model: Inline code before / after a bytecode
 - Inlined code is normal smalltalk code
 - Not much knowledge about bytecode needed

Trace Library



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- > Called from annotated code
- > Builds up the trace

- > Provides
 - Trace model
 - Event pre-processing (ordering)
 - State reconstruction

State reconstruction

- > State not recorded for completely annotated classes
 - past state can be reconstructed from trace
- > System never completely annotated
 - Tracer saves state of non-annotated objects

Debugging system classes

- > Annotate classes used by Bytesurgeon or Tracer
 - System classes (e.g. Collection or String)
 - Compiler (e.g. AST)

- > Problems:
 - Classes used for annotation --> crash
 - Tracer records events generated by the tracer

Solution

- > Retain both methods (original + annotated)
- > Generate preamble
 - test for global
 - call original methods when inactive
- > Common problem when using reflection!
 - General solution?
 - Future work!

Benchmarks



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	Events	Slowdown	Memory (Kb)
Example	74	6	16
AST Bug	2725	3.8	800
Pier Trace	389689	248	88800

Future Work

- > further analyze + improve
 - Memory Consumption (GC effects)
 - Performance

- > Use behavioral reflection
 - fine grained selection
 - Scoping
 - Annotation of system classes

Conclusion

- > Problem of current debugging tools

- > Overview of Unstuck
 - UI
 - Implementation

- > Having the history available helps
 - Possible for small programs
 - Work needed for bigger systems + continuous use

Conclusion

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- > Problem of current debugging tools

- > Overview of Unstuck
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- > Having the history available helps
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Questions?