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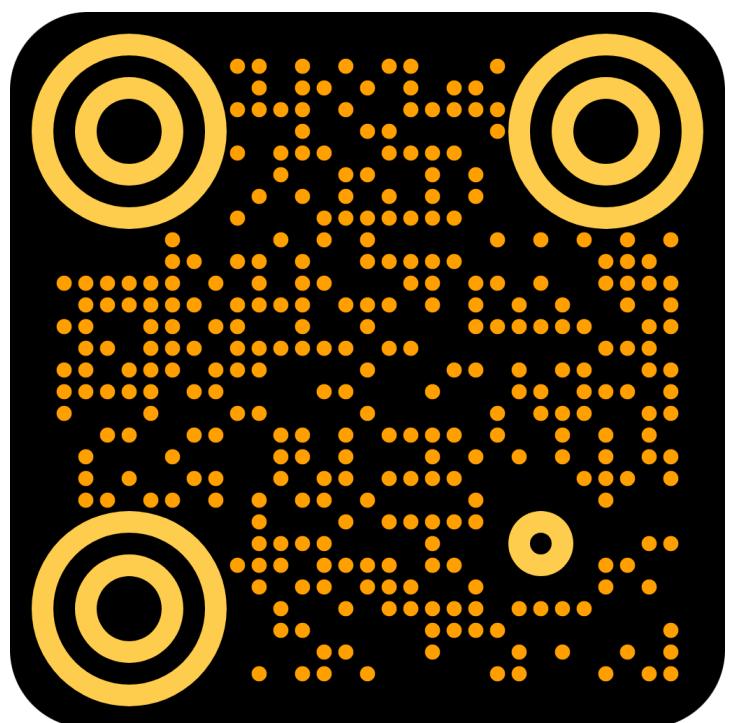
CRISTAL
Centre de Recherche en Informatique,
Signal et Automatique de Lille

Ease Virtual Machine Level Tooling With Language Level Ordinary Object Pointers



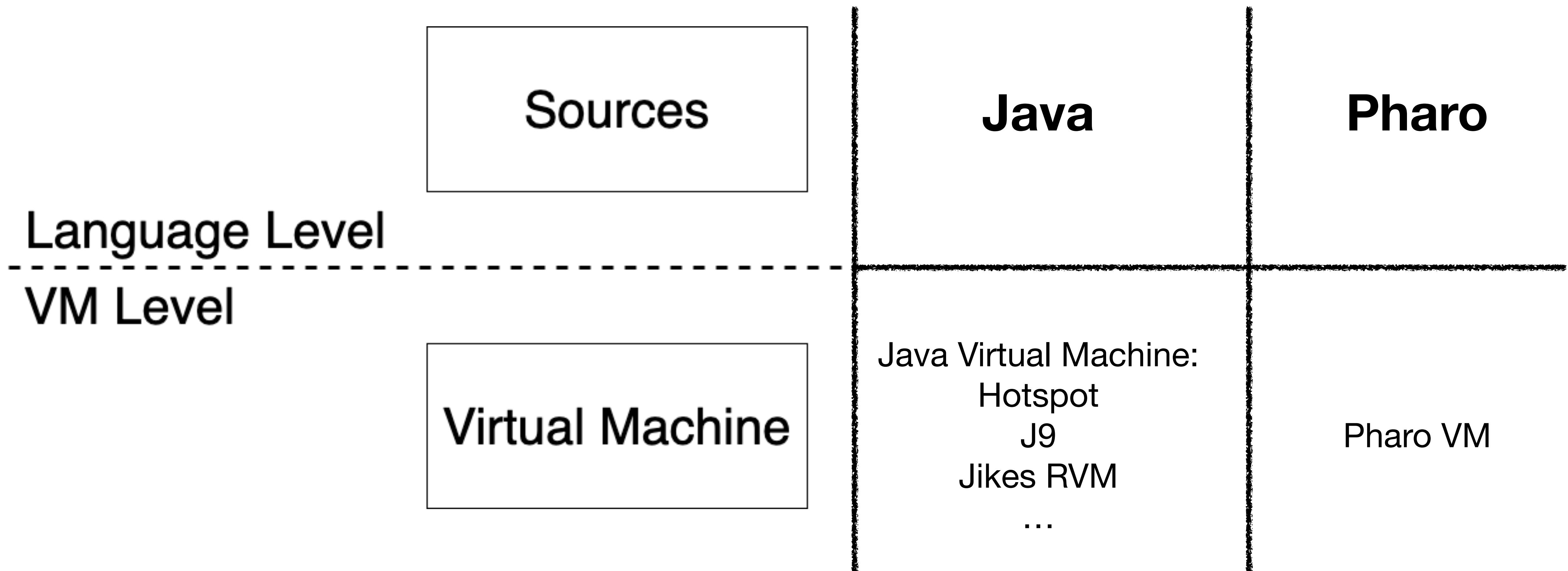
Pierre Misse-Chanabier
Theo Rogliano

VMIL Paper ! ->



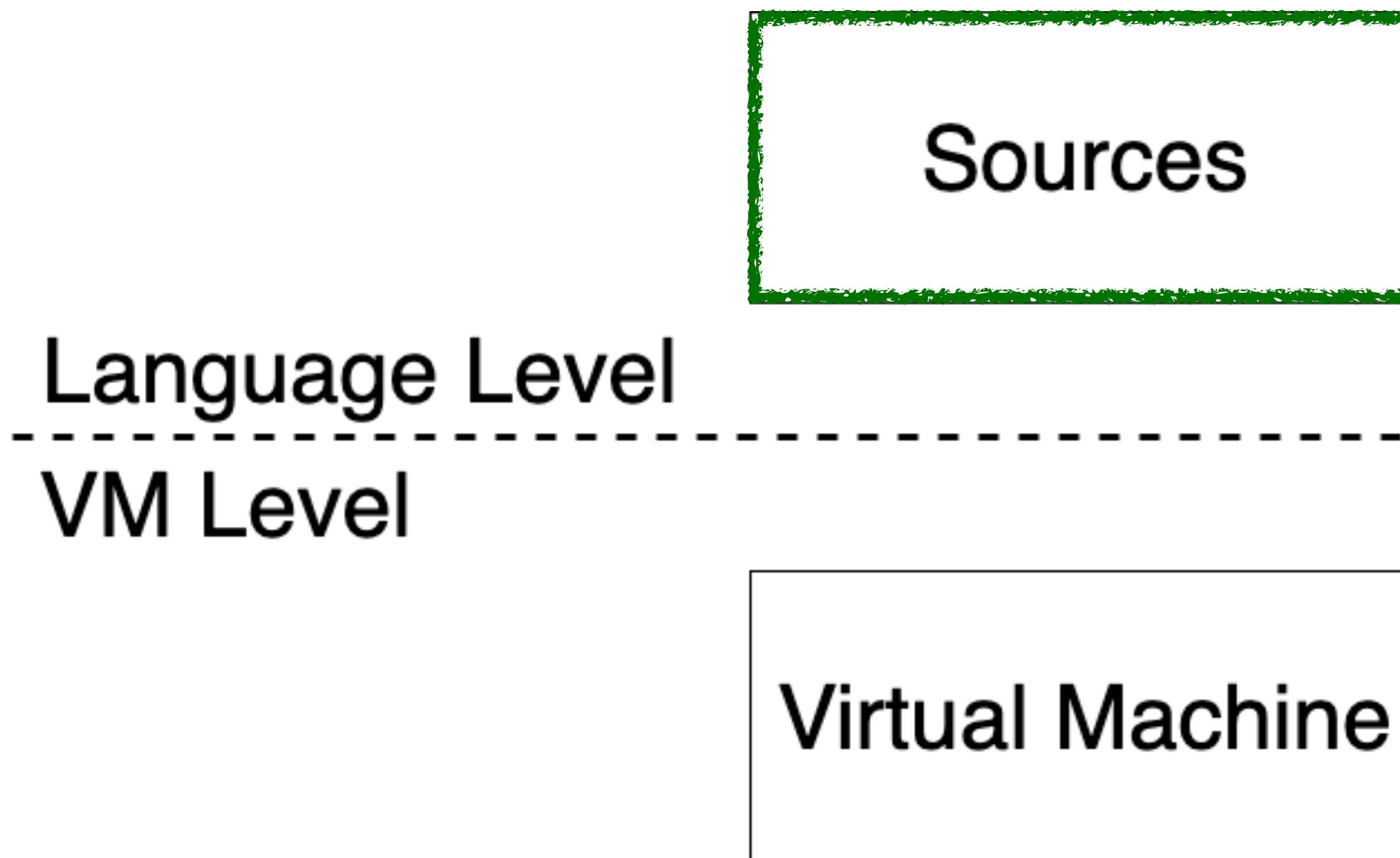
Who Does Not Love Tools ?

Tooling Levels



Who Does Not Love Tools ?

Tools at the Language Level



Debuggers, Profilers, Compilers, Code Browser,
XUnit, Refactoring, Project Management

.....



Who Does Not Love Tools ?

Tools at the VM Level

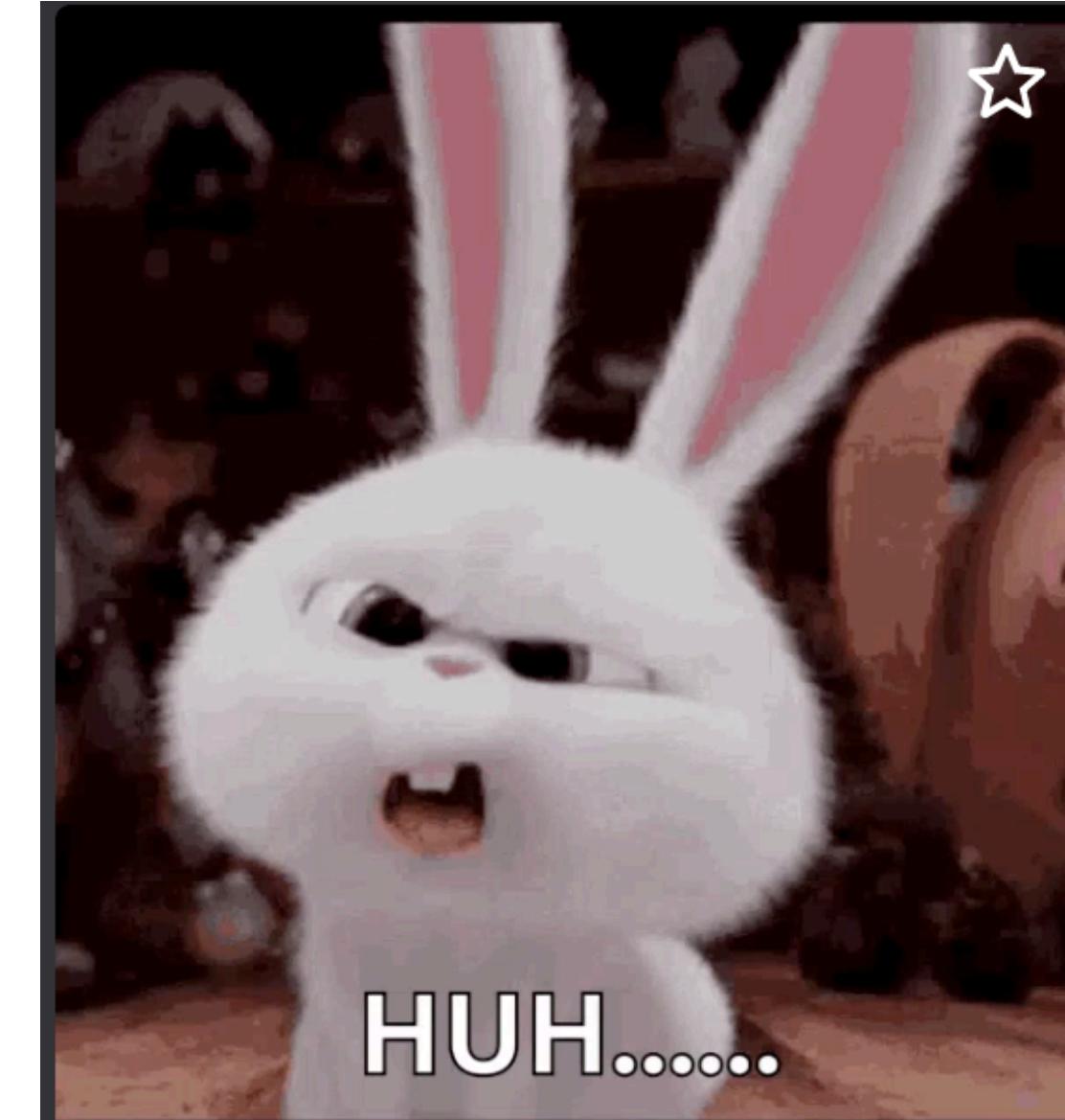
Sources

Language Level

VM Level

Virtual Machine

Debuggers, Profilers, Memory visualisation, Bootstrap
Difficult to write, requires expertise



Who Does Not Love Tools ?

Why Should we Care About VM Level Tools ?

Form >> #scaledByDisplayScaleFactor

1 halt.

^ **self scaledToSize: self extent * self currentWorld displayScaleFactor**

Who Does Not Love Tools ?

Don't Close the Environment !



Form >> #scaledByDisplayScaleFactor

1 halt.

^ self scaledToSize: self extent * self currentWorld displayScaleFactor



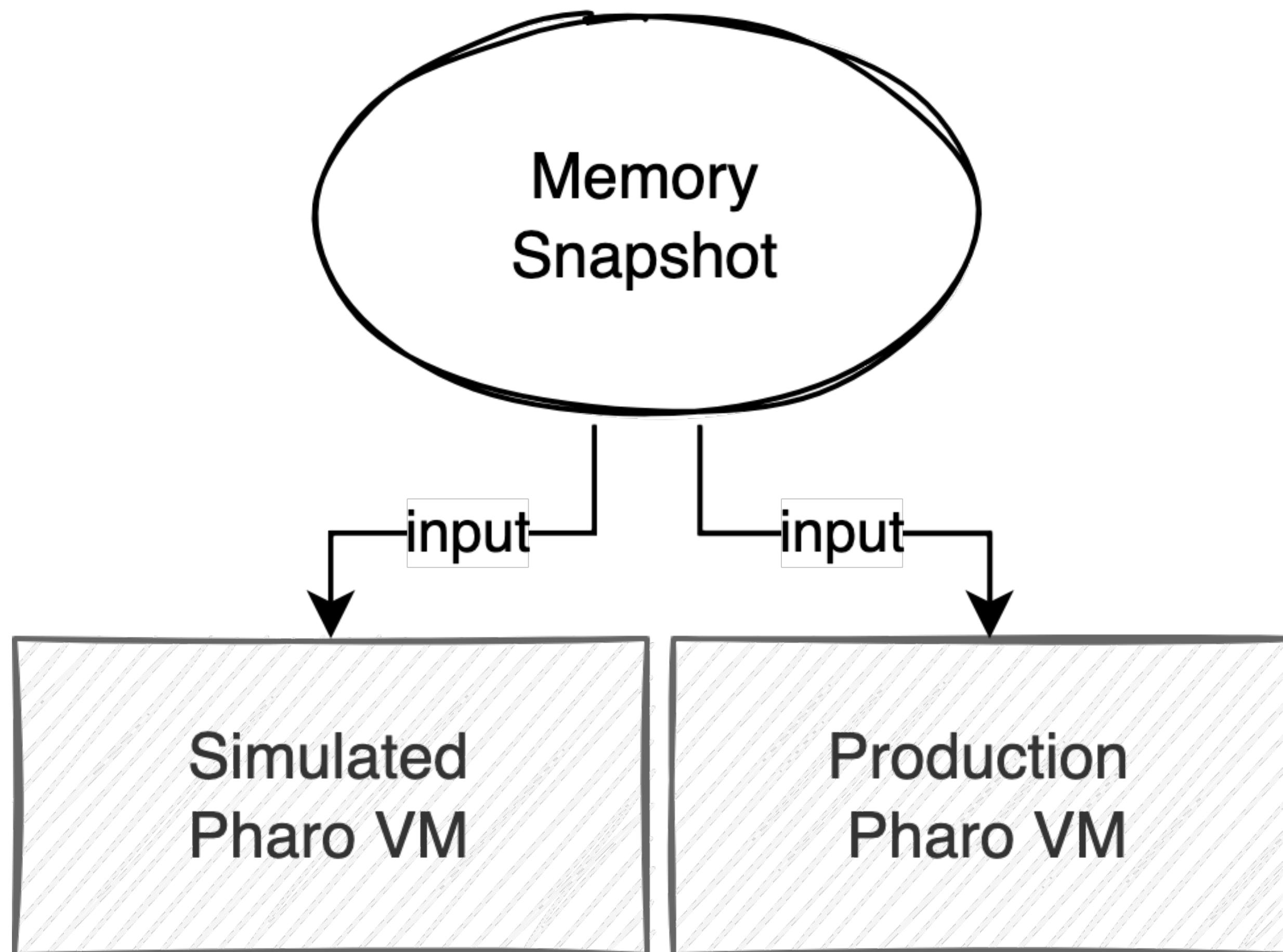
Who Does Not Love Tools ?

We need the VM support !

```
Halt
SmallInteger(Object)>>halt
Form>>scaledByDisplayScaleFactor
ThemeIcons>>iconNamed:
MorphicRootRenderer(Object)>>iconNamed:
MorphicRootRenderer(OSWorldRenderer)>>setAttributesDefault
MorphicRootRenderer class(OSWorldRenderer class)>>forWorld:
[ :arg5 | tmp2 := arg5 forWorld: arg1 ] in AbstractWorldRenderer
FullBlockClosure(BlockClosure)>>cull:
[ :arg4 | (arg1 value: arg4) ifTrue: [ ^ arg2 cull: arg4 ] ] in
arg2 cull...etc...
OrderedCollection>>do:
OrderedCollection(Collection)>>detect;ifFound;ifNone:
OrderedCollection(Collection)>>detect;ifFound:
AbstractWorldRenderer class>>detectCorrectOneForWorld:
```

Let's Code VM Level Tools !

Looking for the Class Form in Memory ...



Let's Code VM Level Tools !

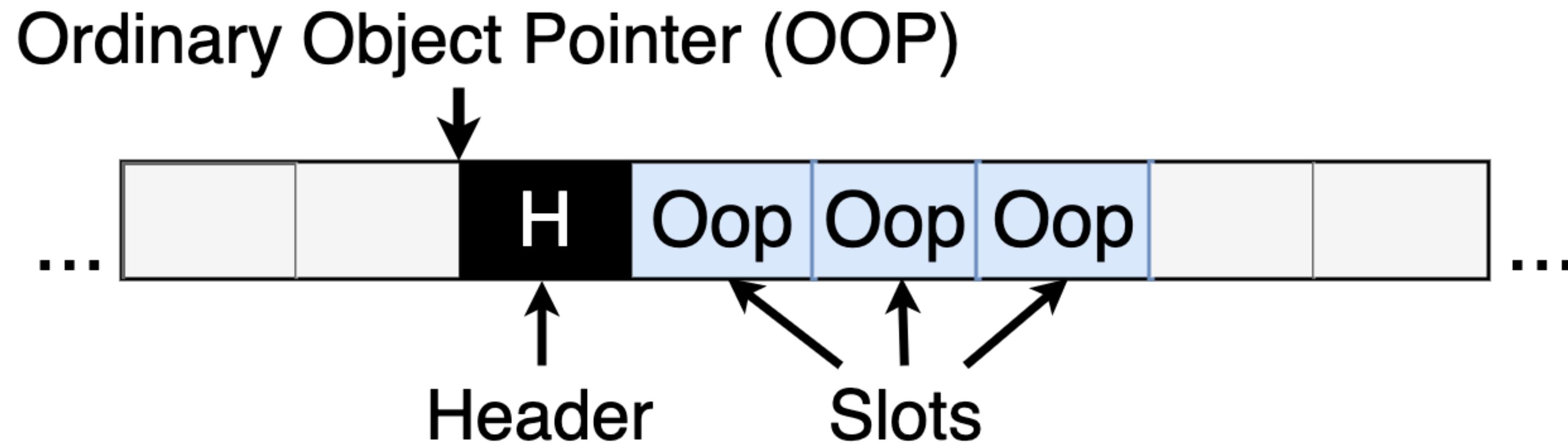
... With the Help of the VM Simulator

```
\200^U^@^@^@^C LanguageEnvironment^@^@^@^@^@^M^L\200^W^@^@^@^C ShortIntegerAr  
ray^@^@^@^@^@^@^@^M^L\200^W\356.^BDiskStore^@^@^@^@^@^@^M^L\200^U\207^@'  
^BMemoryStore^@^@^@^@^@^@^M^L\200^W^@^@^@^BClipboard^@^@^@^@^@^@^M^L\200^Vf  
\234^K^CMCMethodDefinition^@^@^@^@^@^@^M^L\200^R^@^@^@^A Locale^@^@^M^L\200  
Pw\310&^AASTCache^M^L\200^S^@^@^@^BOSEnvironment^@^@^@^@^M^L\200^S\323\2711^C  
InternetConfiguration^@^@^@^M^L\200^P^0k^D^AZnServer^M^L\200^VWB^S^CMCGitHu  
bRepository^@^@^@^@^@^@^M^L\200^U\301] (^DMCGitBasedNetworkRepository^@^@^@^  
@^@^M^L\200^VQa^M^BZnLogEvent^@^@^@^@^@^M^L\200^S^@^@^@^BDisplayScreen^@^  
@^@^M^L\200^R^@^@^@^ACursor^@^@^M^L\200^T^@^@^@^AForm^@^@^@^M^L\200^V^@^@  
^@^BStrikeFont^@^@^@^@^@^M^L\200^S^@^@^@^BFreeTypeCache^@^@^@^M^L\200^U^@  
^@^@^BLogicalFont^@^@^@^@^@^M^L\200^P^@^@^@^BFreeTypeSettings^M^L\200^V^@^@  
^@^BWorldMorph^@^@^@^@^@^M^L\200^V^@^@^@^BCPUWatcher^@^@^@^@^@^@^M^L\200^  
P^@^@^@^BPharoCommonTools^M^L\200^V^@^@^@^BGTPlayBook^@^@^@^@^@^@^M^L\200^W  
^@^@^@^DSystemSettingsPersistence^@^@^@^@^@^@^M^L^@^Q^@^@^@^A Default^@a^L  
^@^A^@^@^@^Gh\224\250^0^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@  
\300\242\371^N^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^@^H\243\37  
1^N^@^@^@^@^M^L^@^S^@^@^@^B priorityLists^@^@^@^@^S^L^@^A^@^@^@^B\200^0\345^N^  
@^@^@^@^@^220t\346^N^@^@^@^@^@^M^L^@^U^@^@^@^C registeredClassName^@^@^@^@^@^S^L  
^@^A^@^@^@^B\200^0\345^N^@^@^@^@^@^8u\346^N^@^@^@^@^@^S^L^@^A^@^@^@^B\200^0\345^  
N^@^@^@^@^@^350u\346^N^@^@^@^@^@^S^L^@^A^@^@^@^B\200^0\345^N^@^@^@^@^@^@^220v\346^N  
^@^@^@^@^@^S^L^@^A^@^@^@^B\200^0\345^N^@^@^@^@^@^350w\346^N^@^@^@^@^M^L^@^T;\22  
6"^\B pushInstVar:^@^@^@^@^M^L^@^S\313\372^G^B storeInstVar:^@^@^@^S^L^@^A^@^@  
^@^B\200^0\345^N^@^@^@^@^@^220x\346^N^@^@^@^@^M^L^@^V^@^@^@^C immediateSubclas  
S:^@^@^@^@^@^@^S^L^@^A^@^@^@^B\200^0\345^N^@^@^@^@^@^8y\346^N^@^@^@^@^@^S^L^@^A^  
^@^@^@^B\200^0\345^N^@^@^@^@^@^210z\346^N^@^@^@^@^@^M^L^@^S^@^@^@^B signalContext  
^@^@^@^@^M^L^@^R^@^@^@^B handlerContext^@^@^@^S^L^@^A^@^@^@^B\200^0\345^N^@^@^@^@^  
@0{\346^N^@^@^@^@^S^L^@^A^@^@^B\200^0\345^N^@^@^@^@^330{\346^N^@^@^@^@^M^
```

Is this it ?

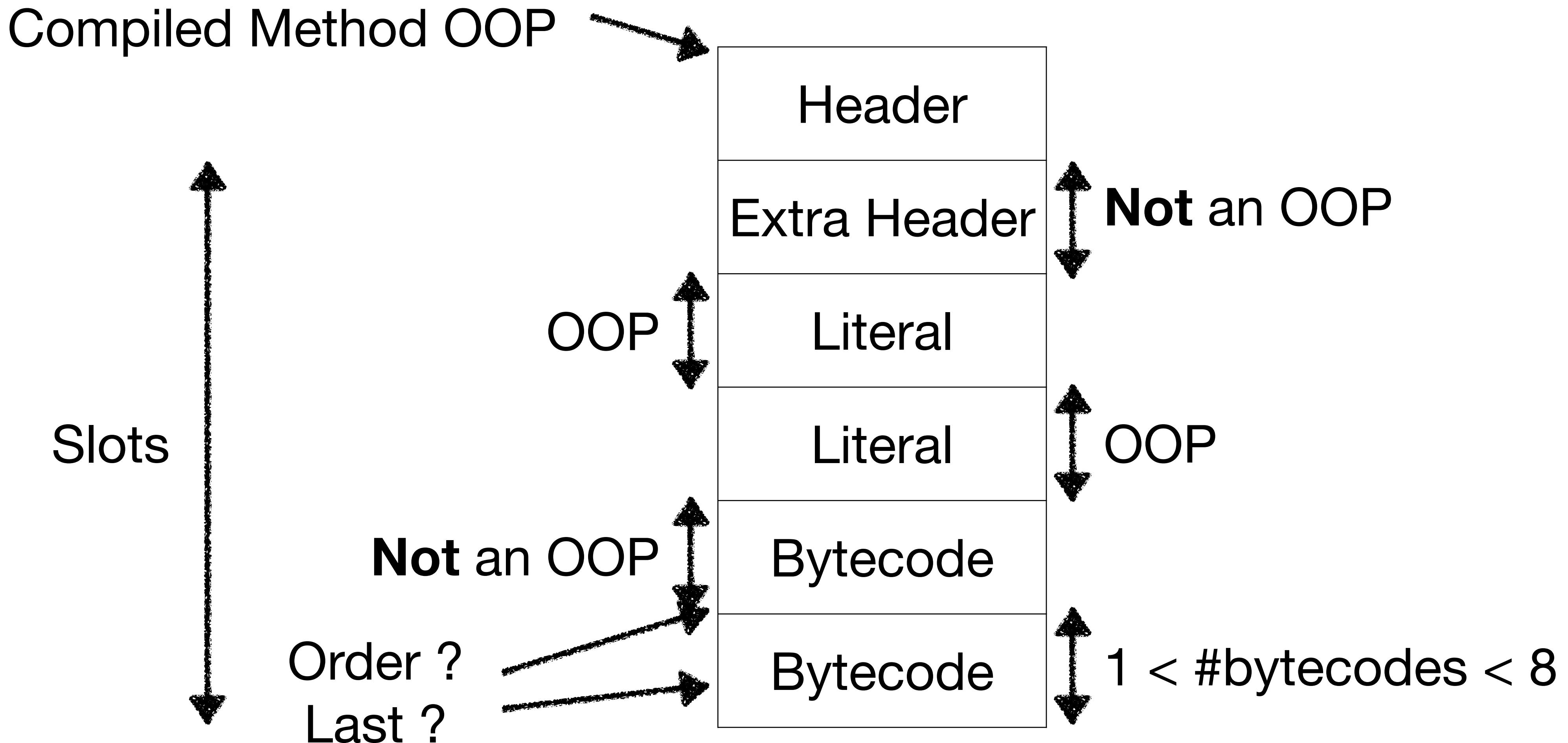
Let's Code VM Level Tools !

Ordinary Object Pointer (OOP)



Let's Code VM Level Tools !

Method Layouts



Let's Code VM Level Tools !

Finding a Class at the VM Level

```
findClassName: aClassName
| classNameIndex classNameOop className |
memory classTableEntriesDo: [ :aClassOop |
    classNameIndex := memory classIndexForOop: aClassOop.
    classNameOop := memory fetchPointer: classNameIndex ofObject: aClassOop.
    className := memory convertStringOopToStringObject: classNameOop.
    className = aClassName ifTrue: [ ^ aClassOop ]].
^ memory nilOOP
```

```
memory findClassName: #Form >>> 406749864
```

Let's Code VM Level Tools !

Knowledge Gaps

findClassName: aClassName

| classNameIndex classNameOop className |

memory classTableEntriesDo: [:aClassOop |

 classNameIndex := memory classNameIndexForOop: aClassOop.

 classNameOop := memory fetchPointer: classNameIndex ofObject: aClassOop.

 className := memory convertStringOopToStringObject: classNameOop.

 className = aClassName ifTrue: [^ aClassOop].

^ memory nilOOP

VM level hidden OOP

Low level style

OOP based API

OOP

memory findClassName: #Form >>> 406749864

Let's Code VM Level Tools !

Knowledge Gaps Recap

Issues

- Ordinary Object Pointers (OOP)
- API manipulating OOPs
- VM level information

Polyphemus

Introducing LLOOPs

Language Level OOPs

Issues

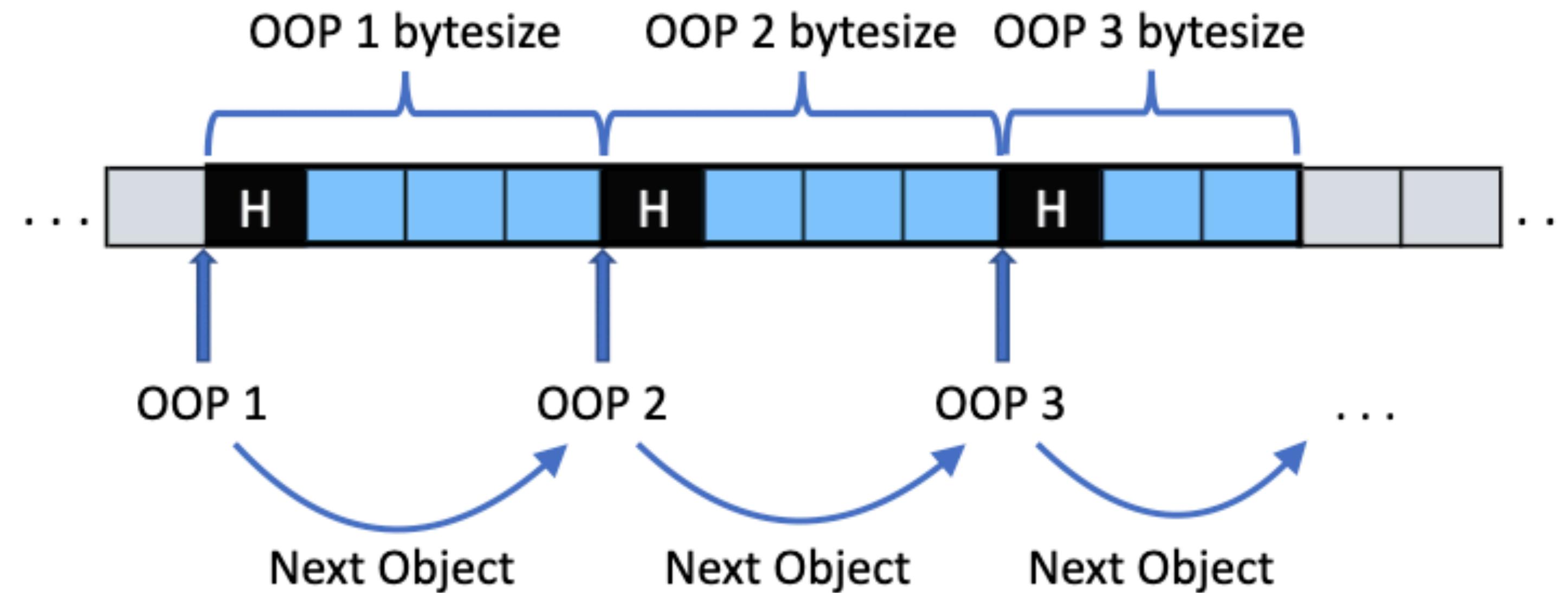
- Ordinary Object Pointers (OOP)
- API manipulating OOPs
- VM level information

Solutions

- Language Level Entities
- Identifying and Typing OOP
- VM and Language level information

Polyphemus

Iterating the Memory



Polyphemus

Identifying the Each OOP

OOP	OOP	OOP	OOP
-----	-----	-----	-----

Is it a Class ?

Is it a Metaclass ?

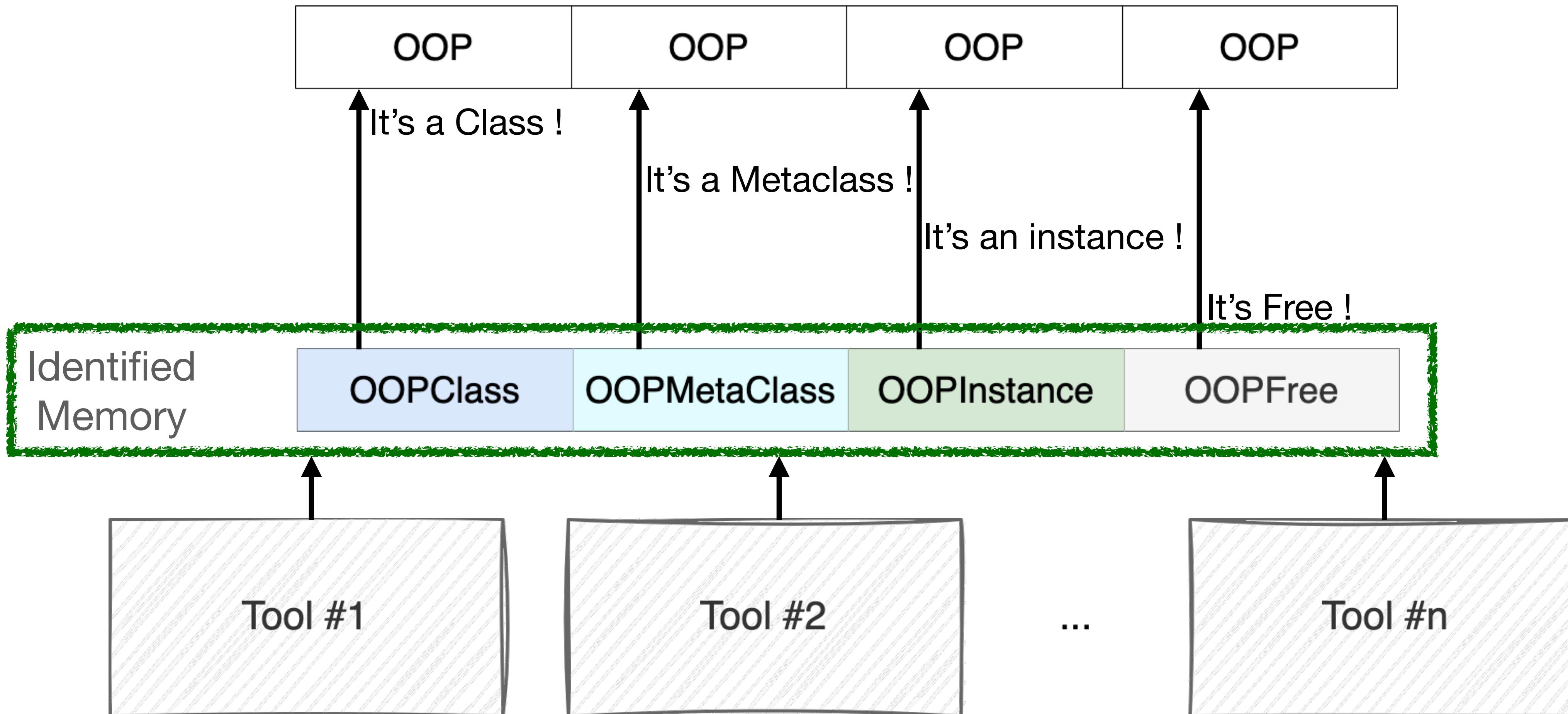
Is it a Free Object ?

Is it a [...] ?

If no particularity, it's an instance !

Polyphemus

LLOOP based tools



Polyphe^mus Tools

Writing Tools

```
identifiedMemory allClassesOop.
```

```
identifiedMemory reifiedMetaclass.
```

```
identifiedMemory allClassesOop select: [ :o | o isClassSide ].
```

```
identifiedMemory objects
```

```
    select: [ :o | o isCompiledMethodOop ]
```

```
    thenCollect:[ :aCompiledMethod |
```

```
        [ aCompiledMethod decompile ] on: Error do: [ nil ].
```

Polyphemus Tools

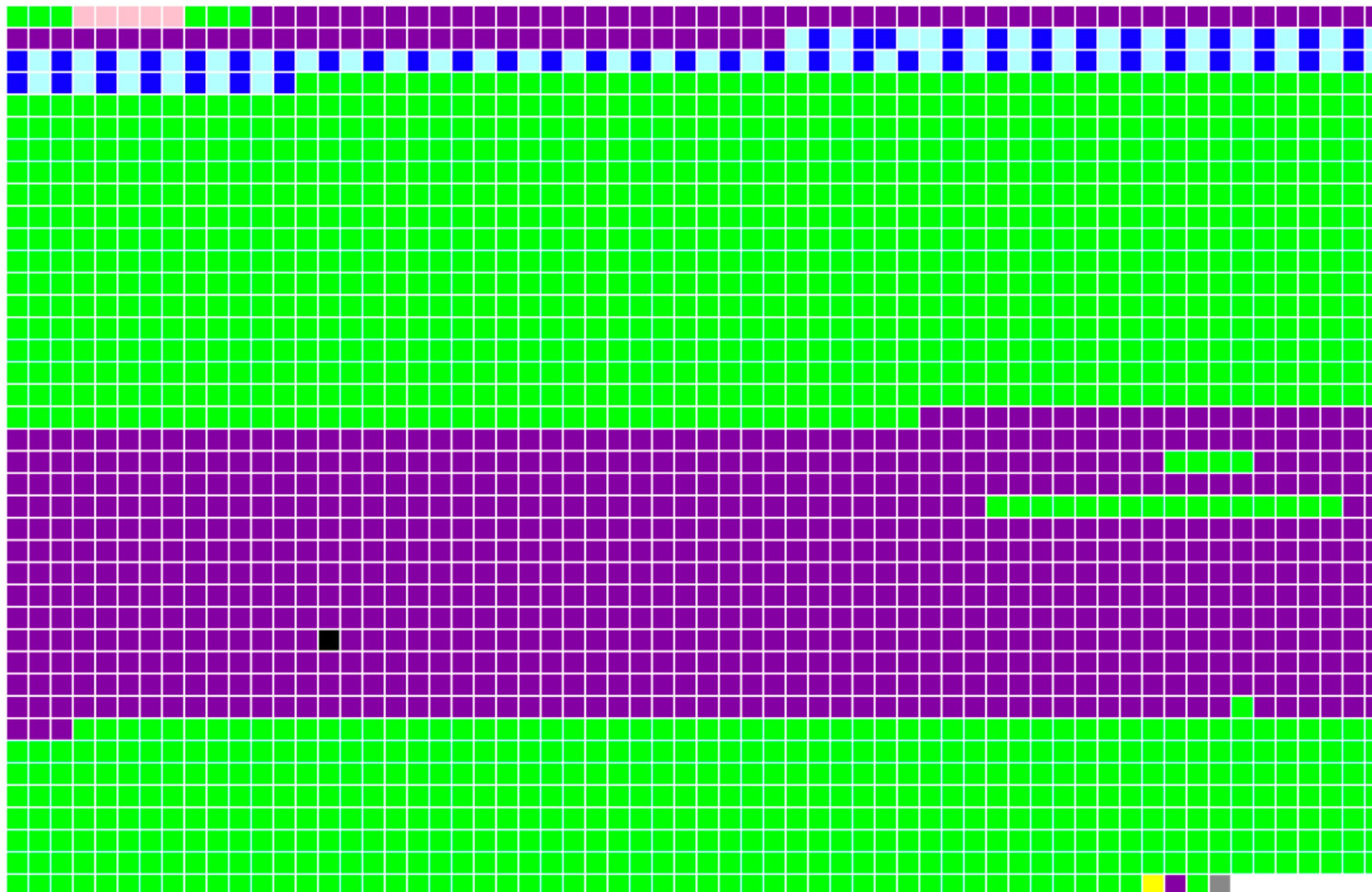
Inspectors

Compiled Method OOP

address	4676295184
printString	Form >> #scaledByDisplayScaleFactor
header	101000000000000000000000000000001100000000000000110000011101
class	CompiledMethod
oopClassTag	3101
format	Compiled method (24)
hash	0
pinned	false
space	Old Space
immutable	false
selector	scaledByDisplayScaleFactor
methodClass	Form
numLiterals	7
numBytecodes	16
bytecode	an Array [16 items] (76 128 216 76 76 129 76 130 131 104 148 92 118 1 0 253)
literal 1	halt
literal 2	extent
literal 3	currentWorld
literal 4	displayScaleFactor
literal 5	scaledToSize:
literal 6	Instance of AdditionalMethodState
literal 7	Instance of GlobalVariable

Polyphemus Tools

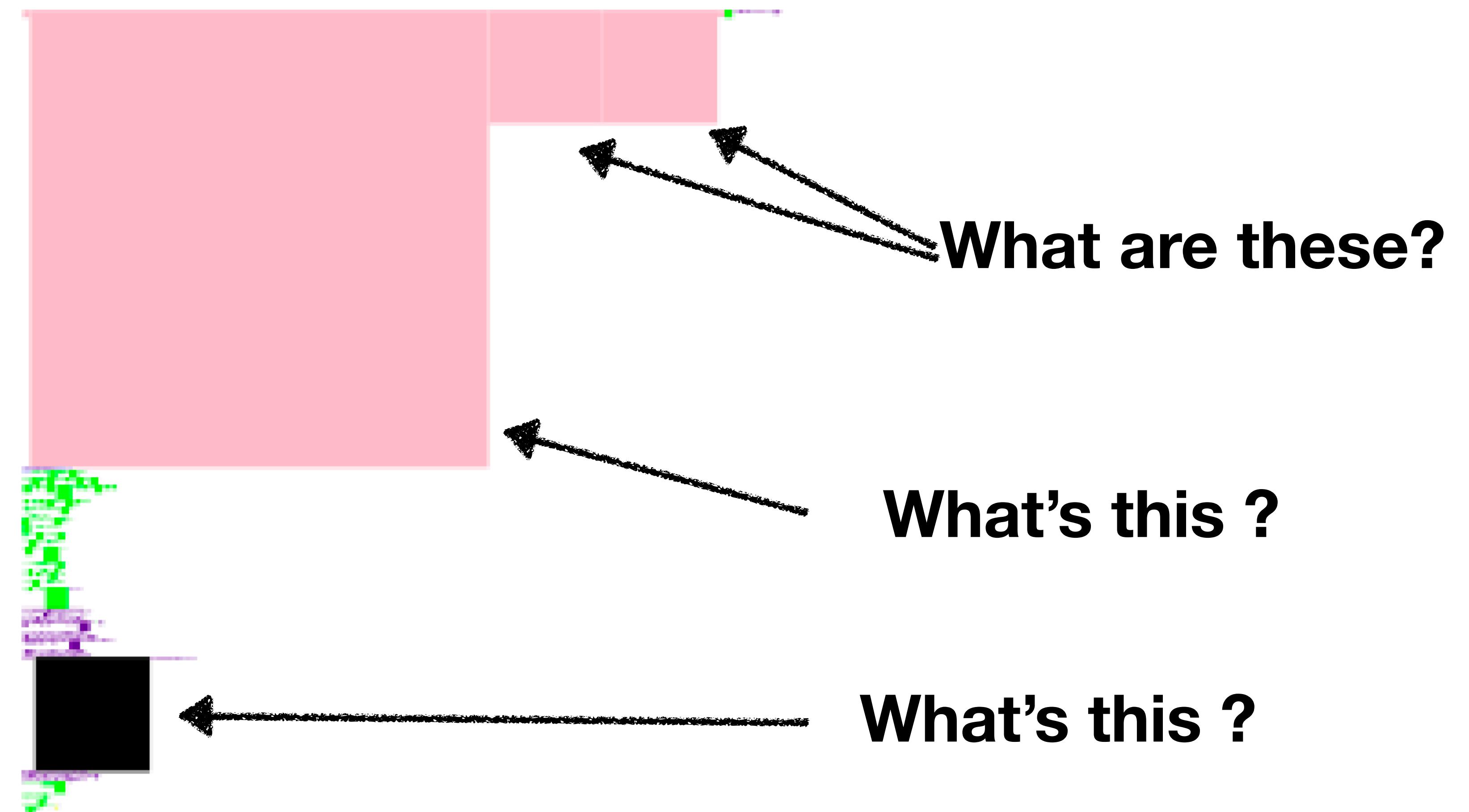
Memory visualisation



- 1 ■ pinned object
- 895 ■ compiled method
- 51 ■ class
- 5 ■ special object
- 1 ■ context
- 1 ■ free chunk
- 1468 ■ regular object
- 51 ■ metaclass

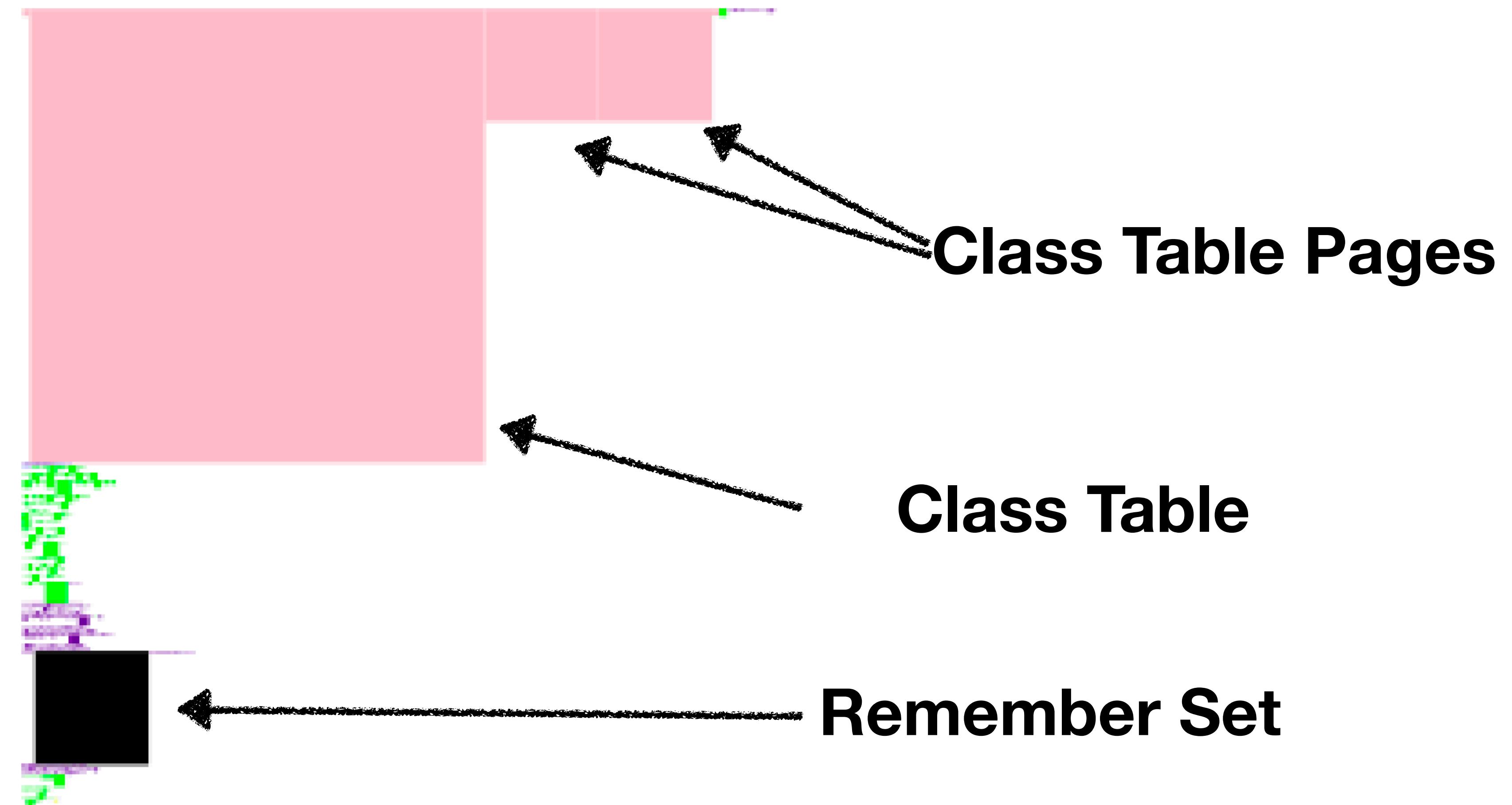
Polyphemus Tools

Evaluating Memory Size



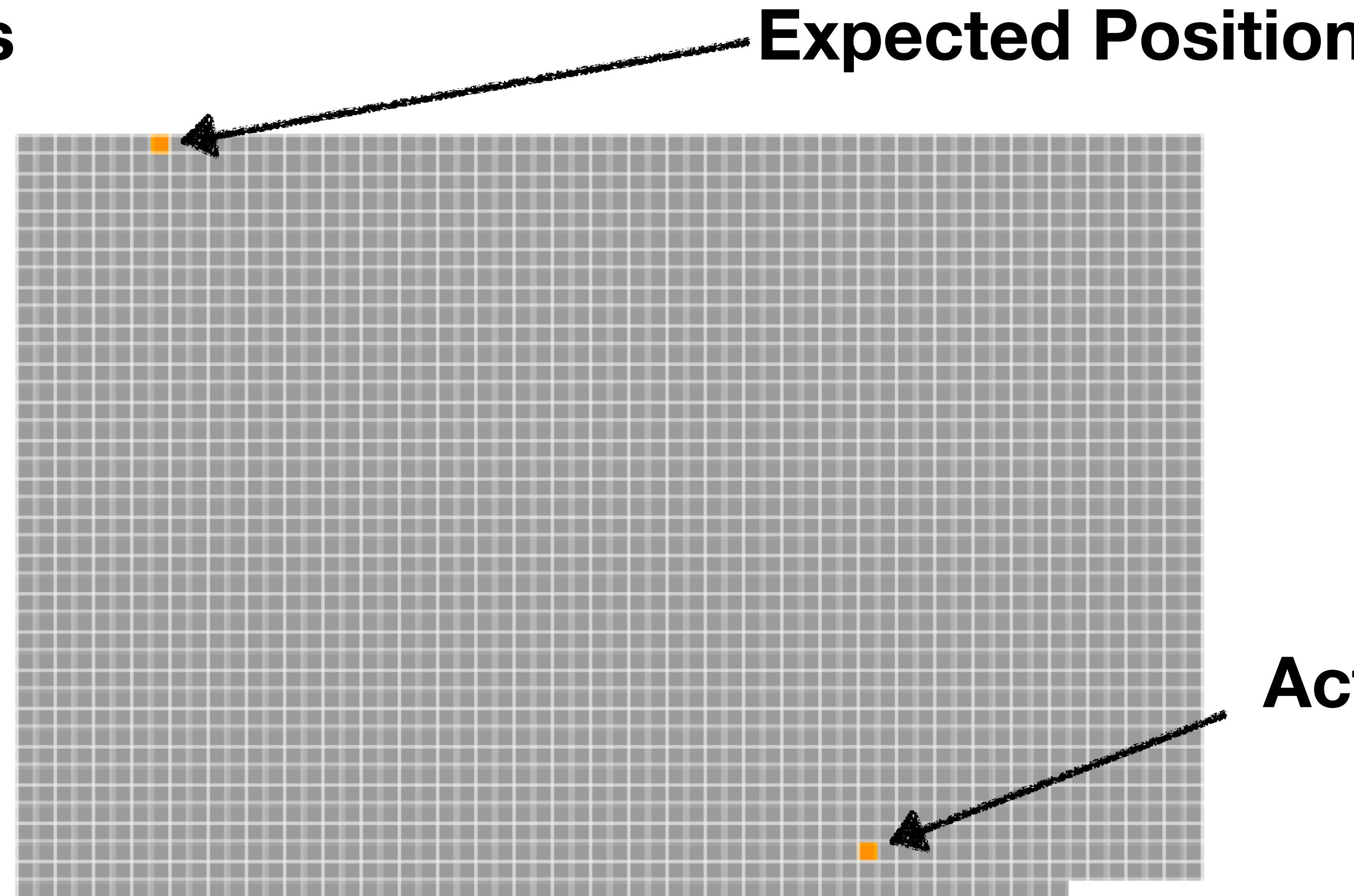
Polyphemus Tools

Evaluating Memory Size

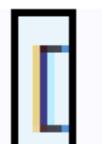


Polyphemus Tools

Named Objects



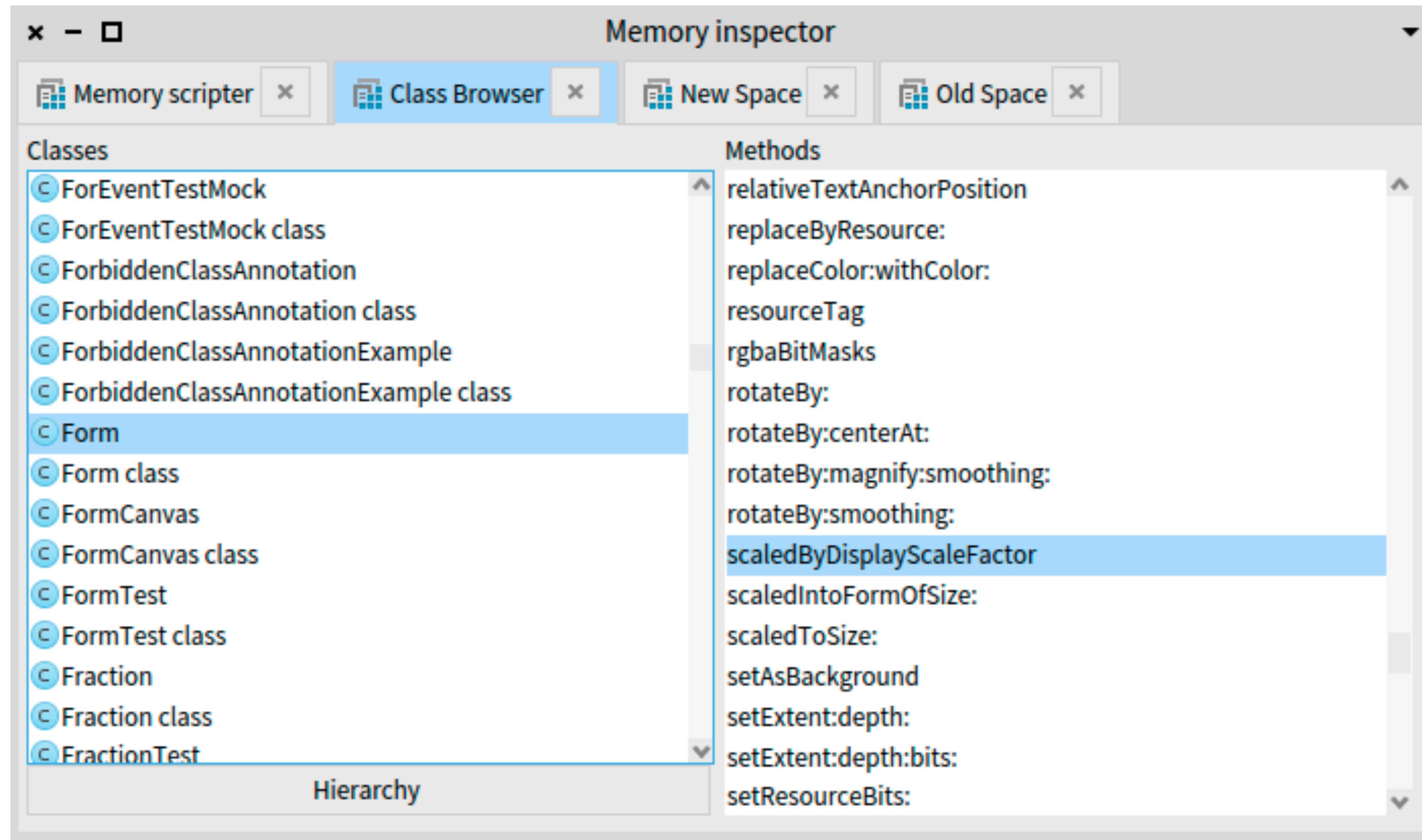
Selecting



:anOop | anOop numSlots = 60]

Polyphemus Tools

Memory Visualisation #2



Real World Bug Fix #1

A Meta-Error

Form >> #scaledByDisplayScaleFactor

1 halt.

^ self scaledToSize: self extent * self currentWorld displayScaleFactor.



Real World Bug Fix #1

Investigating

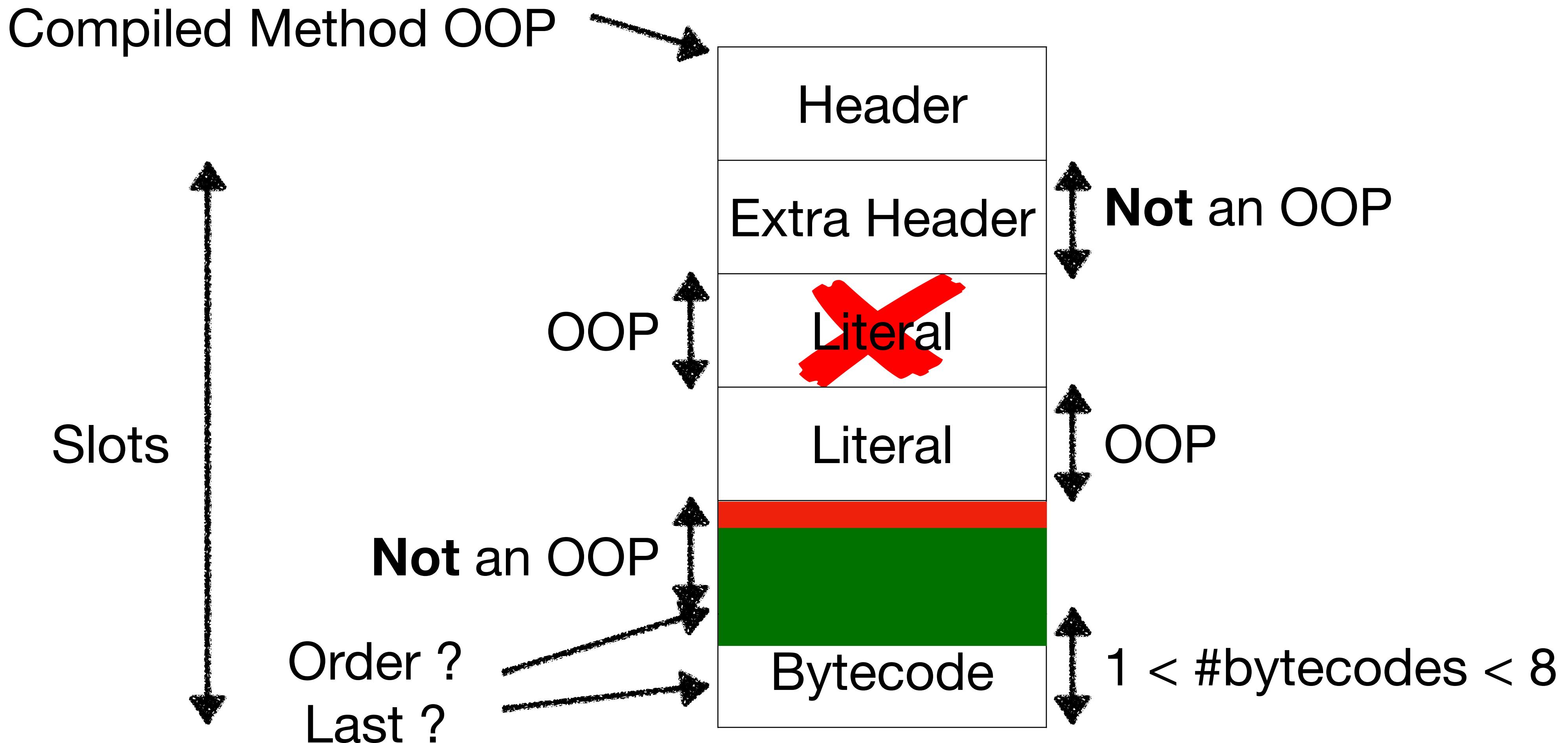
→ bytecode an Array [16 items] (76 128 216 76 76 129 76 130 131 104 148 92 118 1 0 253)
bytecode an Array [13 items] (76 76 128 76 129 130 104 147 92 50 42 158 252)

literal 1	halt
literal 2	extent
literal 3	currentWorld
literal 4	displayScaleFactor
literal 5	scaledToSize:
literal 6	scaledByDisplayScaleFactor
literal 7	Instance of GlobalVariable

literal 1	extent
literal 2	currentWorld
literal 3	displayScaleFactor
literal 4	scaledToSize:
literal 5	scaledByDisplayScaleFactor
literal 6	Instance of GlobalVariable

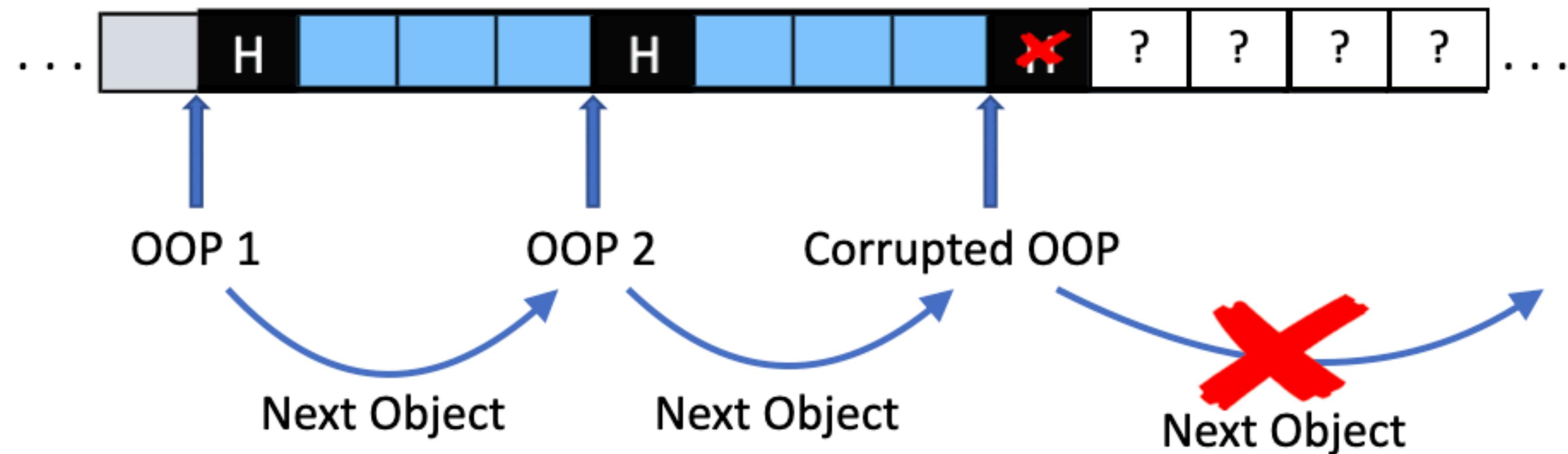
Real World Bug Fix #1

Method Patching Analysis



Real World Bug Fix #2

Iterating the Corrupted Memory



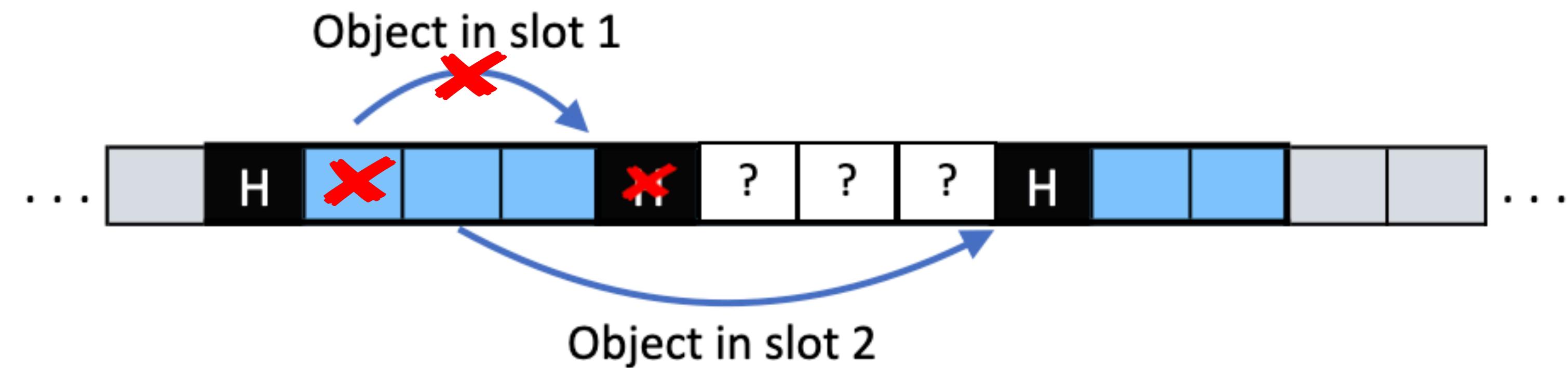
Real World Bug Fix #2

We don't know what's after

Oop Oop Oop Oop ?

Real World Bug Fix #2

Recovering Objects



Real World Bug Fix #2

Tracking The Corruption

Oop	Oop	Oop	Oop	Oop	Oop	C	Oop	Oop	Oop	Oop
Oop	Oop	Oop	F	Oop						
Oop	Oop	C	Oop	Oop	Oop	F	Oop	Oop	Oop	Oop
Oop	F	Oop	F	Oop	C	Oop	Oop	Oop	Oop	Oop
Oop	Oop	F	Oop	Oop	Oop	Oop	F	Oop	Oop	Oop

Real World Bug Fix #2

Cleansing The Corruption

Oop	Oop	Oop	Oop	Oop	Oop	F	Oop	Oop	Oop	Oop	Oop
Oop	Oop	Oop		F	Oop						
Oop	Oop		F	Oop	Oop	Oop		F	Oop	Oop	Oop
Oop		F	Oop	F	Oop		F	Oop	Oop	Oop	Oop
Oop	Oop		F	Oop	Oop	Oop	Oop	Oop	F	Oop	Oop

Real World Bug Fix #2

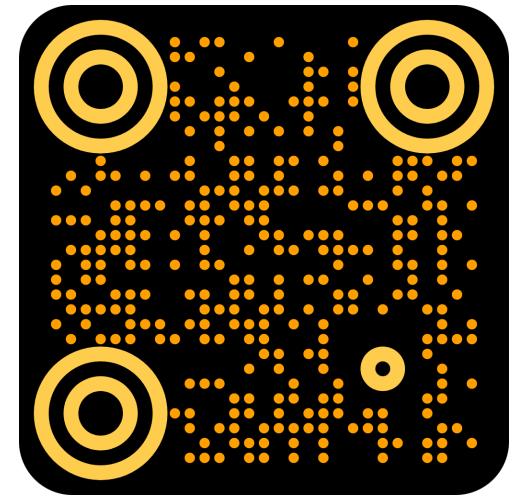
Corruption Cleansing Analysis

- Objects' slots iteration
- Reference patching
- Focus on learning rather than how to do the previous items

Conclusion

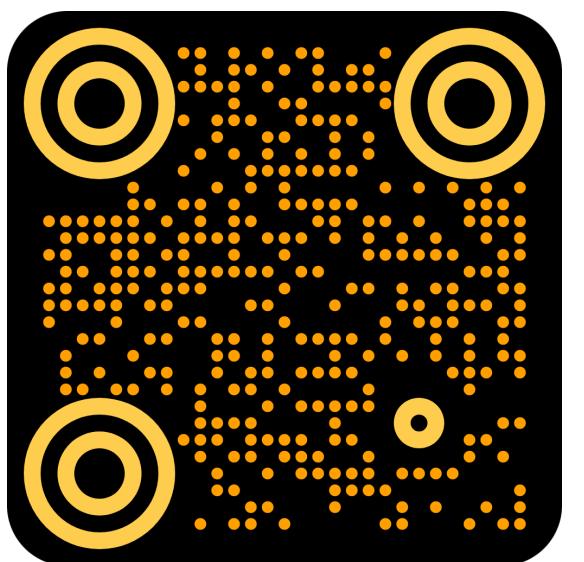


Github

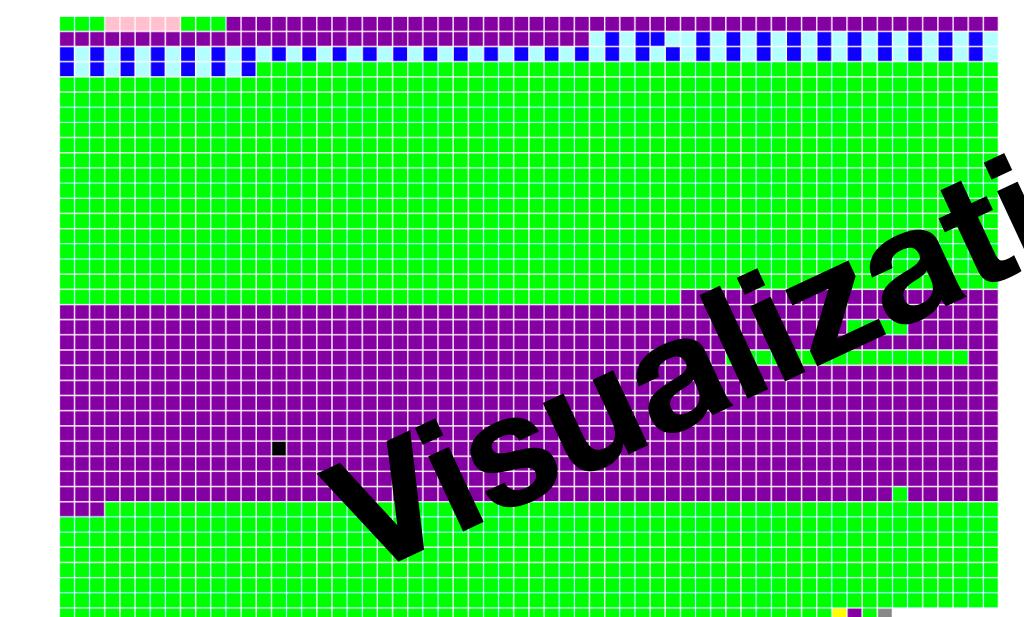


- Tooling at the VM level is difficult
 - LLOOPs bridge knowledge gaps
 - Language Level entities
 - Identifying and typing OOPs
 - Mix Language and VM level informations

Paper



Pierre Misce-Chanabier
pierre misse25@msn.com
github.com/hogoww
Discord tag: hogo#8547



Key	Value
address	406749864
printString	Form
header	101100000000000011100110010000000100000000000000011100110001
class	Form class
oopClassTag	1841
format	Non Indexable (1)
hash	1842
pinned	false
space	Old Space
immutable	false
numSlots	11
superclass	DisplayMedium
methodDict	Instance of MethodDictionary
format	65541
layout	Instance of FixedLayout
organization	Instance of ClassOrganization
subclasses	Instance of Array
name	Form
classPool	Instance of Dictionary
sharedPool	nilObject
environment	Instance of SystemDictionary
category	Graphics-Display Objects-Forms