Virtual Smalltalk Images: Model and Applications

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The context: Pharo

- Object oriented language
- Dynamic typing
- Highly reflective
- Image based
- Metacircular

Going meta has limitations[1,2]

Metacircularities

- hidden and uncontrollable dependencies e.g.,
  - core libraries (e.g., #do: iteration method)
  - core tools (e.g., compiler, debugger)
- Once broken, they are not easily reconstructed
- VM still needed for many tasks (e.g., process manipulation)

[1] Bootstrapping reflective languages: the case of Pharo, Polito et al. 2012 (in submission)
[2] The meta in meta-object architectures, Denker et al. 2008

Some existing solutions

- Casaccio et al. 's object spaces[3] allowed atomic operations on classes
- Bootstrapping a Smalltalk[1] allowed the recreation of an entire Smalltalk system to alter metacircularities
- Pharo's emergency evaluator allows recovery of some critical errors
- Debugging/modifying the virtual machine to have complete control
- Changes file allows code recovery
- Ad-hoc solutions (copy the class, modify copy, replace...)

[1] Bootstrapping reflective languages: the case of Pharo, Polito et al. 2012 (in submission)
[3] Object spaces for safe image surgery, Casaccio et al. 2009

What we would like from a reflective system

- Full control
- Atomicity of changes
- Interactive
- High level tools for system recovery
- Recovery of both code and application data

Our solution: Virtual images with Object Spaces

- An **full** image is contained and controlled by another image
- The container image is the **host**
- The contained image is the **guest**
- An **Object Space**[1] reifies the guest image and allows the host to manipulate it as an object

[1] Gwenaël Casaccio, Damien Pollet, Marcus Denker, and Stéphane Ducasse. Object spaces for safe image surgery. In Proceedings of ESUG International Workshop on Smalltalk Technologies (IWST'09)

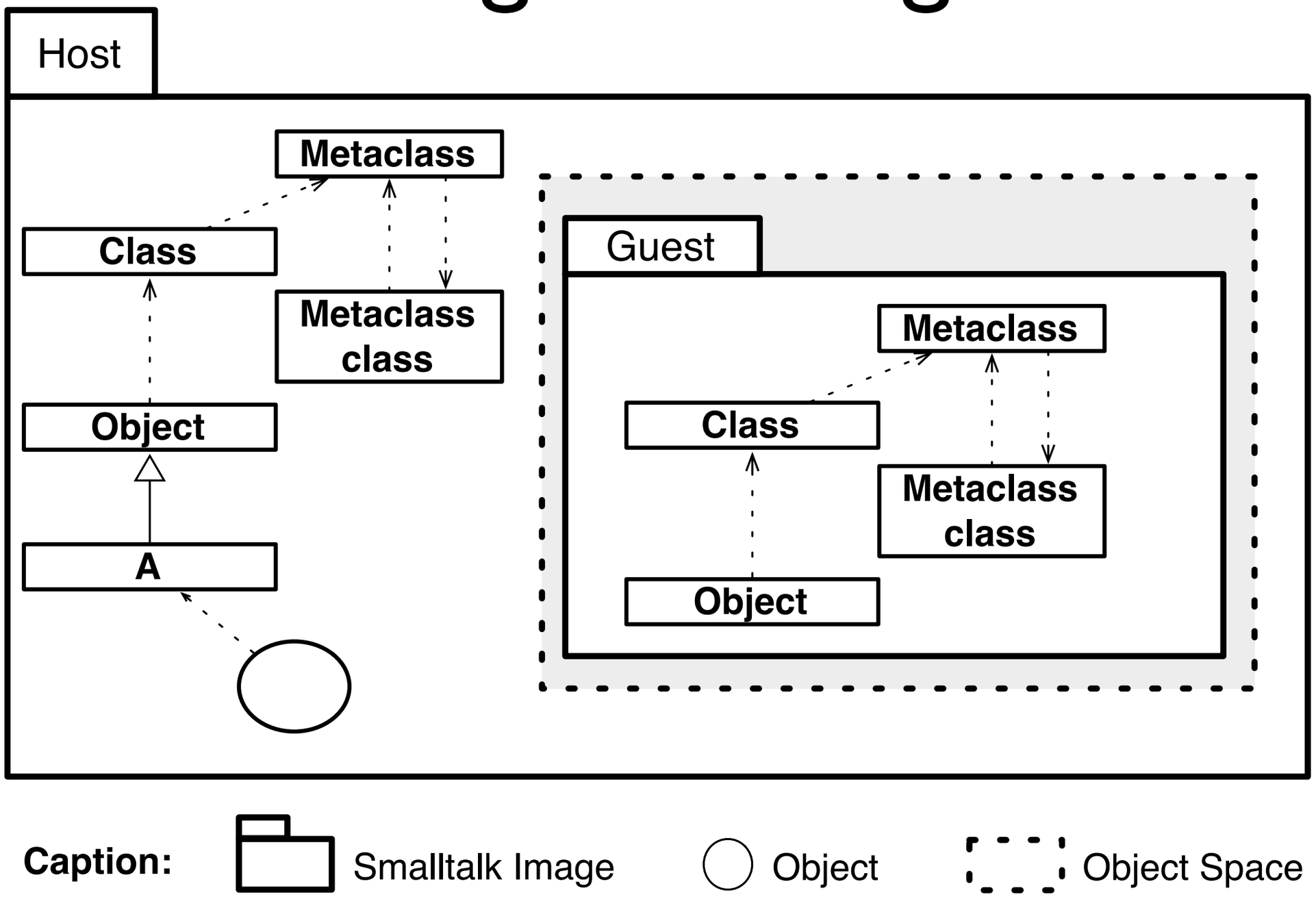
Object Spaces

Oz Object Spaces
the model

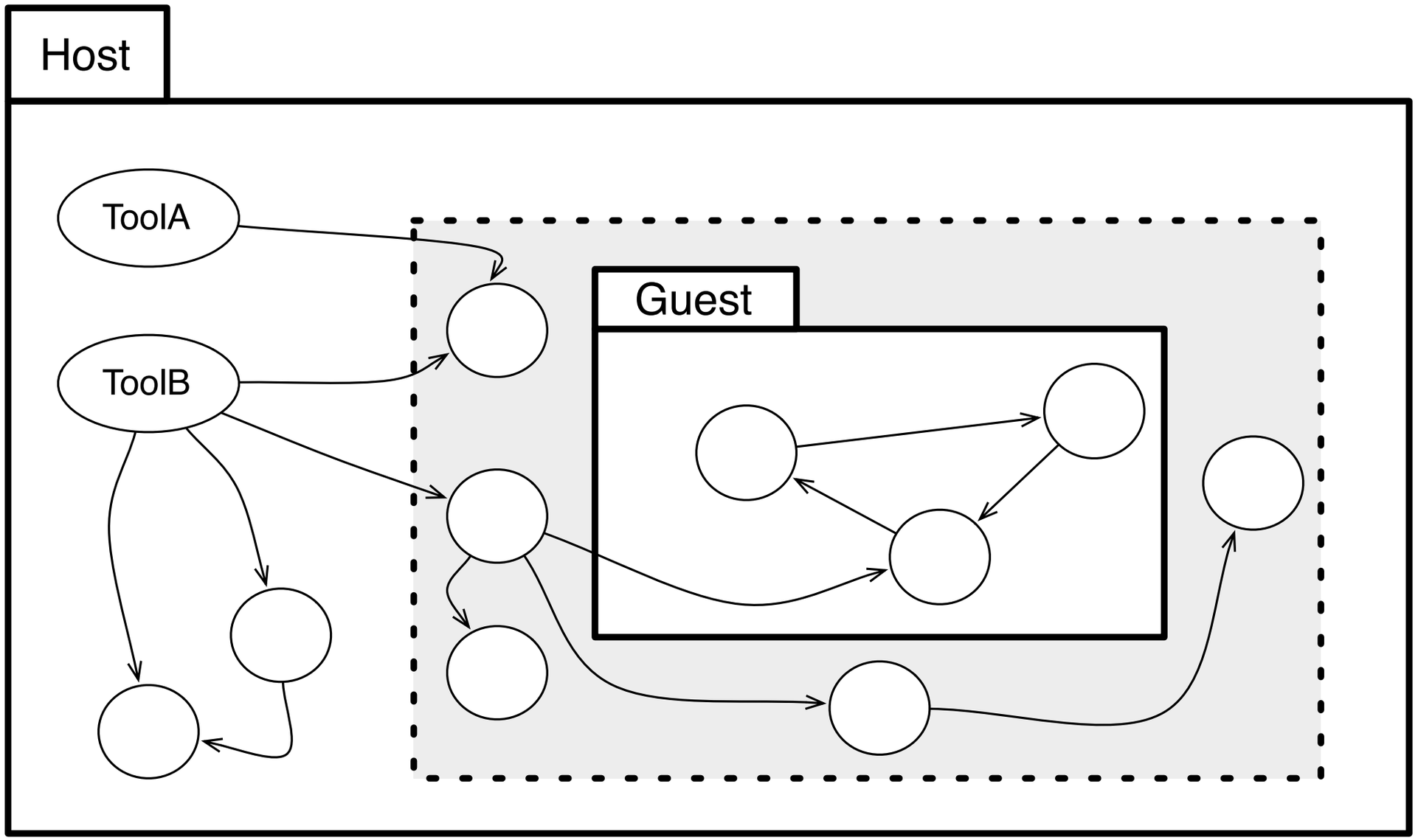
A reification of a Smalltalk image with two main components:

- The **guest image** it contains and encapsulates
- A **membrane** of objects controlling the communication between host and guest objects

Oz Object Spaces
the guest image



Oz Object Spaces the membrane



Caption: Smalltalk Image Object Object Space

Oz Object Spaces membrane: the façade

- The object space façade is the concrete reification of the guest image
- Access to well known objects in the object space. e.g., nil, true and false
- Access to classes in the object space
- Conversion of literals form the host to the guest, and viceversa

Oz Object Spaces membrane: mirrors

- Direct object manipulation
  - Field manipulation: get and set values from object fields
  - Size calculation: get the size of objects
  - Class access: introspect and modify the class of an object
  - Testing and conversion operations. e.g., #isNil, #asBoolean
- Some mirrors provide specialized operations. e.g., a ClassMirror supports the #basicNew operation

Oz Object Spaces control of execution

- Full control of an object space processes via mirrors i.e., create, suspend, resume and terminate processes and alter values of their associated contexts
- Provide controlled windows of time for execution to an object space

Oz Object Spaces control of communication

- One way communication: host to guest
- Communication is achieved by creating and injecting objects into the object space
- Mirrors ensure that object injection is safe and fulfills the transitive closure property
- Sending messages: the particular case of injecting a process with the desired code and introspect its result after finished
- Literal translation from and to guest and host

Oz Object Spaces applications

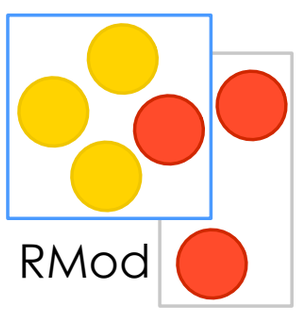
- Image surgery
- Image recovery and better Emergency Kernel
- Controlled interruption
- Image side Stack overflow and infinite loop detection
- Sandboxing

The Vision

- Many versions of the system running side by side
- Controlling resources at the language level
- Secure
- Completely modifiable and adaptable (while running)
- Specialized for particular needs
- With tools to analyze, modify and fix a system
  - System surgeon
  - System browsing and debugging

Virtual Smalltalk Images: Model and Applications

- Oz Object spaces reify full Pharo images
- Irrestricted manipulation of guest's objects through mirrors
- Control of guest's execution



Behind Oz Object Spaces: the implementation

Oz Object Spaces
the implementation

We implemented Oz on top of Pharo20:

- Virtual machine support for multiple images
- Image side library to install in the host (implementing the membrane objects)

Oz Object Spaces
Challenging infrastructure

- **Special Objects Array:** an array the VM uses to understand the running image objects i.e., the nil, true and false instances, the compact classes, etc
- **Green Threads:** concurrency is managed with reified user-level threads, the Process instances. No real multithreading is supported
- **VM Single Interpreter Assumptions:** global variables all around, plugin are single-interpreter aware

Oz Object Spaces memory layout

Host and Guest images share the same heap

- Reuse of VM memory mechanisms
- No extra VM support to handle cross-image references
- Shared garbage collection

Oz Object Spaces mirror implementation

Mirrors manipulate objects through two main primitives:

- Execute a method on an object
- Try a primitive on an object

Mirror hierarchy based on roles and internal structure

- ObjectMirror, ByteObjectMirror, WordObjectMirror
- ClassMirror, MethodDictionaryMirror, ProcessMirror

Oz Object Spaces process manipulation

- Processes are simple objects
- In the host, they are represented through ProcessMirror, ProcessSchedulerMirror and ContextMirror
- Mirrors allow manipulation and maintain consistency of the process model

Oz Object Spaces context switch

Execution of code inside an object space is based on a context switch:

1. The VM installs the object space as the current environment to run
2. Runs until being preempted
3. Gives control back to the host

Oz Object Spaces
Pharo image contract

An image contract is composed by:

- **Services:** reachable objects from the image's root. e.g., nil, true, false, the SystemDictionary. They appear in the *special objects array (the root object of an image)*.
- **Format of the objects:** amount and meaning of the instance variables of core objects. They are configured in the membrane.

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