The CLOSER: Automating Resource Management in Java

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  - Operating system resources: Files, sockets, ...
  - Window system resources: Fonts, colors, ...
  - Application specific resources: Listeners, model view control pattern, ...

Motivation

Application Specific Resources

```
public class SomeView {
    private SomeListener l;
    private WorkbenchWindow w;

    public void createPartControl(Composite parent) {
        l = new Listener(this);
        w.addPerspectiveListener(l);
    }

    public void dispose(){
        w.removePerspectiveListener(l);
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We call m the **obligating** method and m' the **fulfilling** method.

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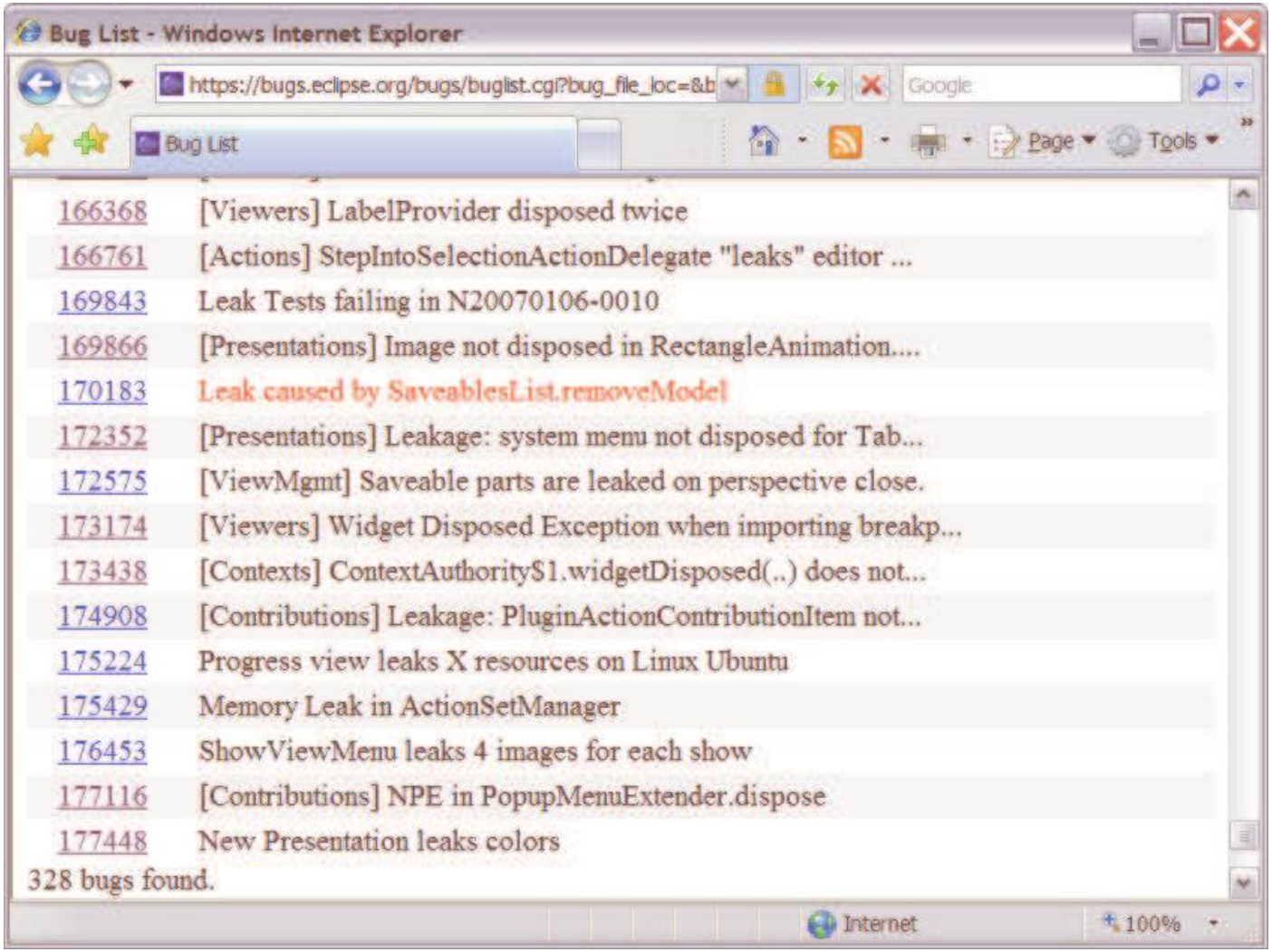

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  - In current JVM implementations, program might run out of non-memory resources before finalizers are called
  - Asynchronous with respect to last use point
- Language Based Solutions
  - e.g., weak references: works where premature disposal is not detrimental, but not a general solution

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- Should not restrict programming patterns.

Challenges

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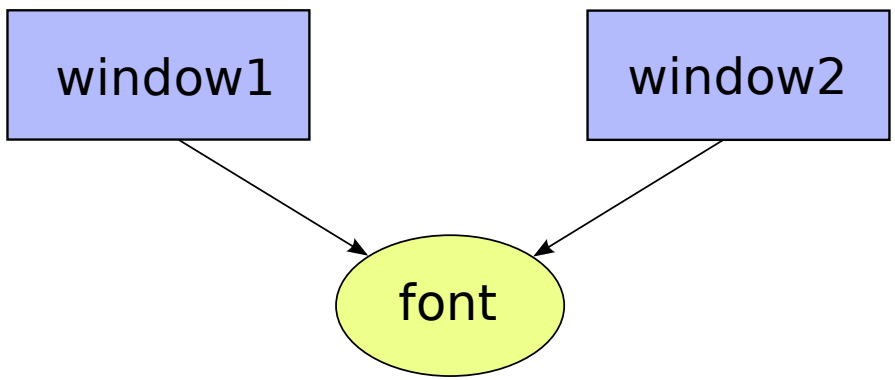
A Font object is shared between two Window objects:



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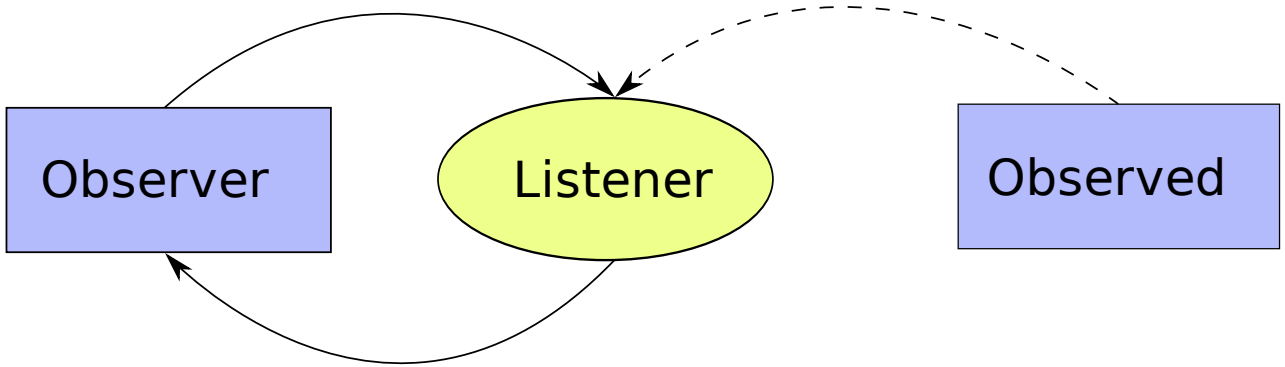
The reference from the Observed object to the Listener is a **non-interest link**:



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    It is not always possible to determine the correct dispose point of the resource purely statically.
- Traditional notion of reachability is not adequate for reasoning about resource lifetimes.
  - Consequence:
    Refined notion of reachability = Interest Reachability

Overview of Our Approach

- The user annotates:
  - the set of **primitive resources**

Overview of Our Approach

```
class WorkbenchWindow {

  private Listener l;

  @Obligation(obligates = ``removePerspectiveListener'',
              resource=1)
 public void addPerspectiveListener(Listener l);
  ...

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  - and later automatically synthesizes `dispose` methods.
- CLOSER statically analyzes resource lifetimes to identify how and where each resource should be disposed.
- CLOSER automatically inserts any appropriate resource dispose calls into source code.

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- σ_E is a mapping from edges to a boolean value identifying whether that edge is an interest or non-interest edge

Example RIG

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public class BufferPrinter {
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   public BufferPrinter(Buffer buf) {
      this.buf = buf;
      this.listener =
         new BufferListener(this);
      buf.addListener(listener);
      this.socket = new Socket();
      socket.connect();
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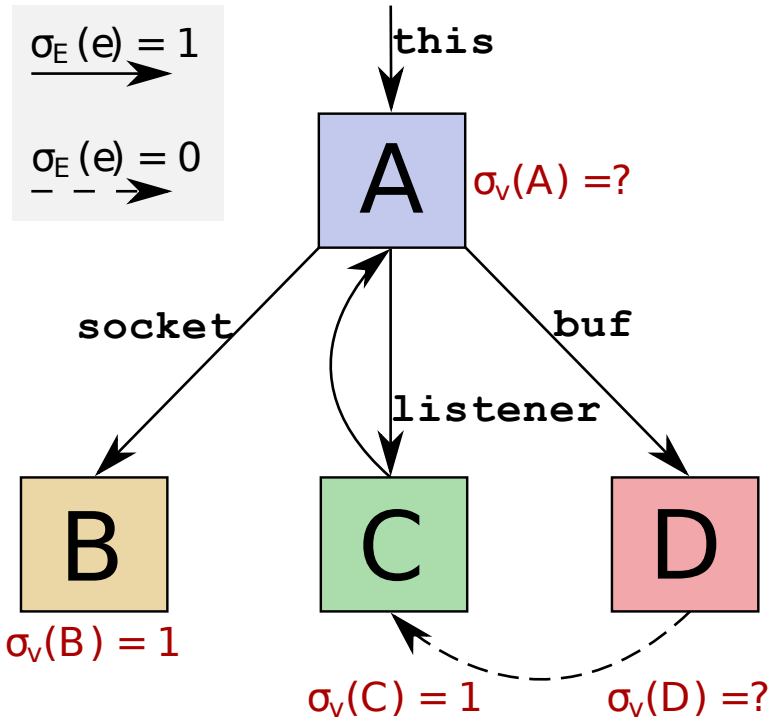

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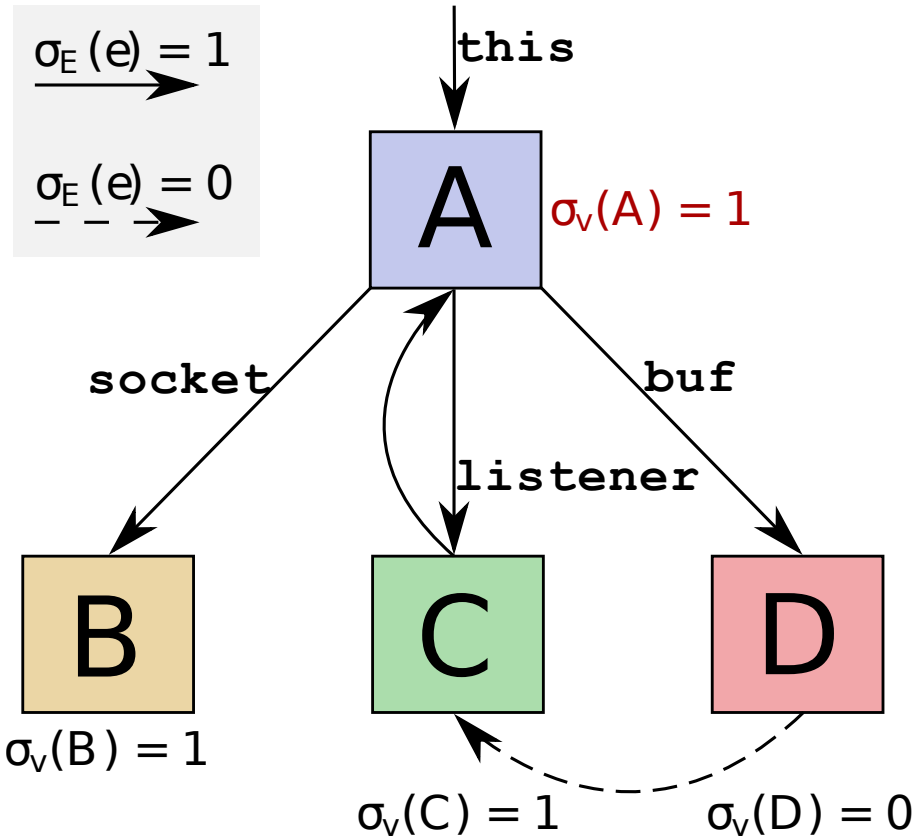
- $\mathcal{T}$'s constructor becomes an obligating method
- and the `dispose` method synthesized by CLOSER becomes the corresponding fulfilling method.

Higher-Level Resource Example



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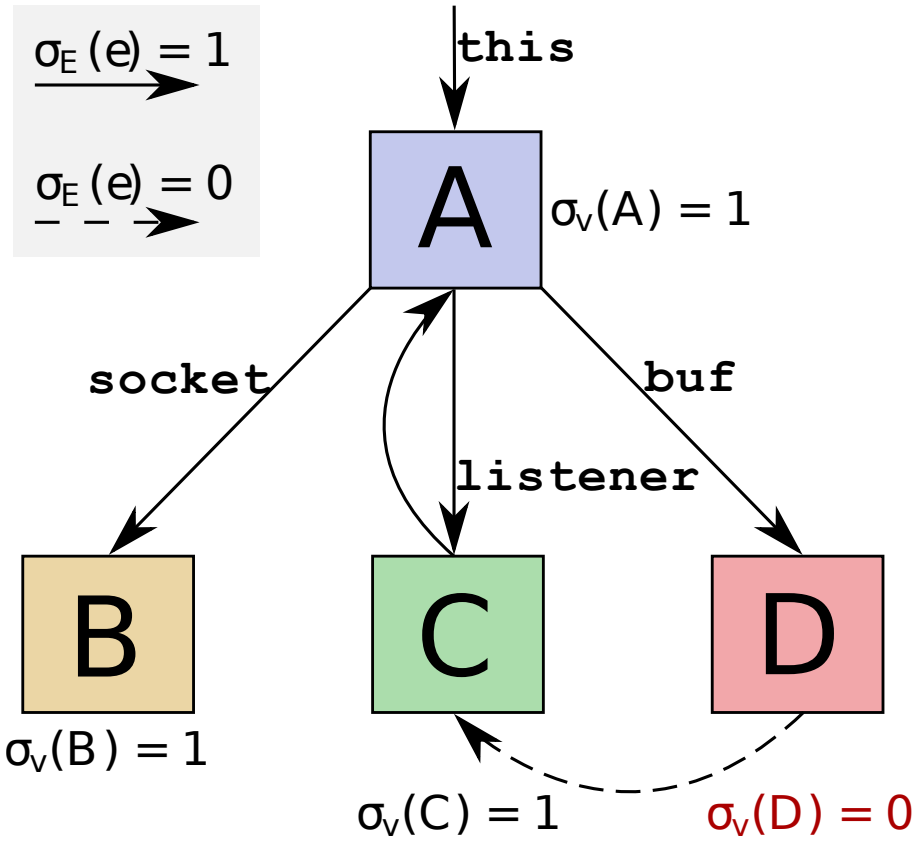

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  - Checks whether the resource's obligating method was called before disposing it.
- Dynamic dispose
  - Requires keeping a run-time "interest-count"
  - Needed whenever CLOSER infers that resource may be shared.

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  - Then by doing data flow analysis to ensure that the inferred solicitor candidates "agree" at every program point.

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- If such a unique path exists, then $l.f_1...f_n$ is designated as a solicitor candidate for r
- If the inferred solicior candidates for r are consistent, then r is disposed through the cascading series of dispose calls initiated by l`.dispose()`, invoked after the last use point of l

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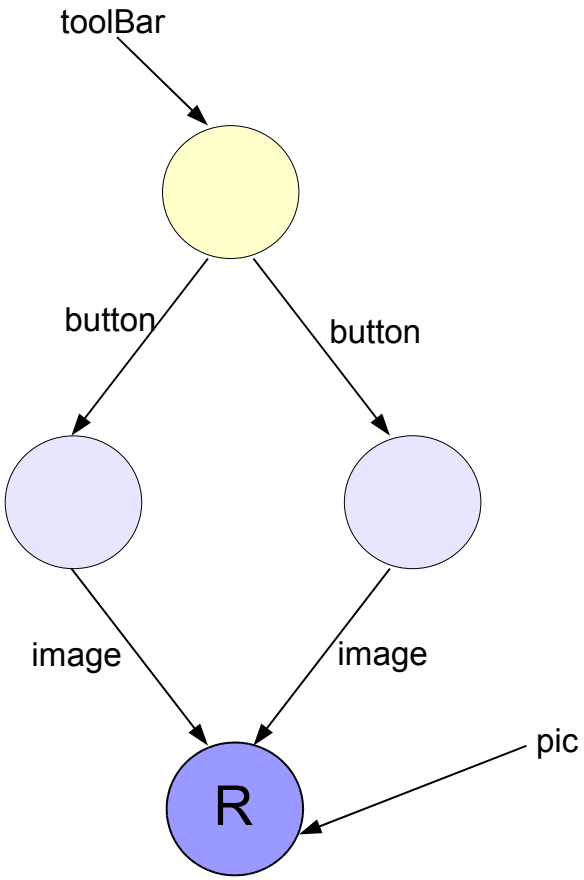

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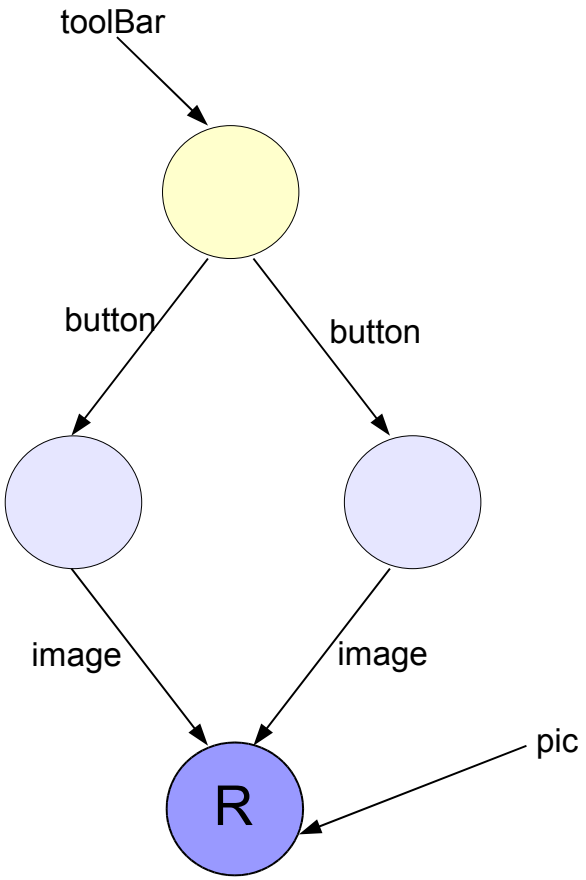

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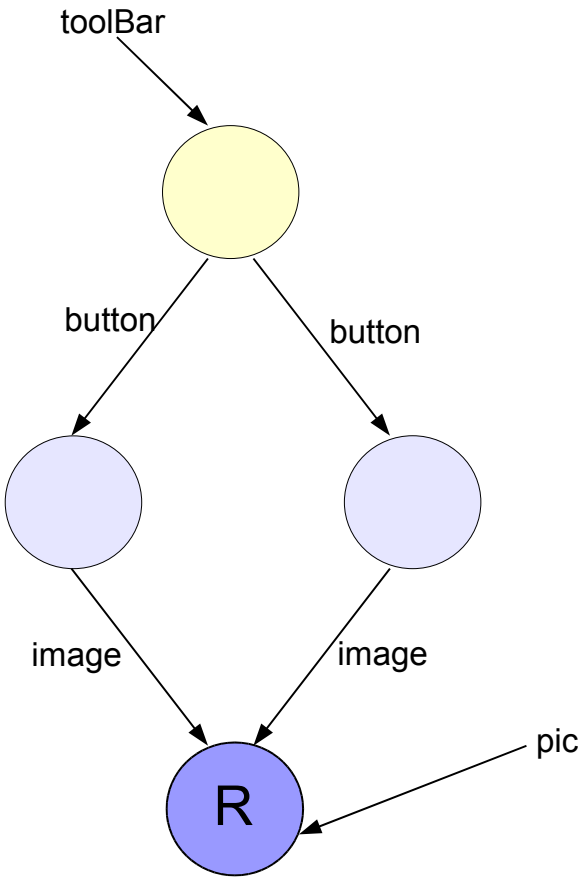

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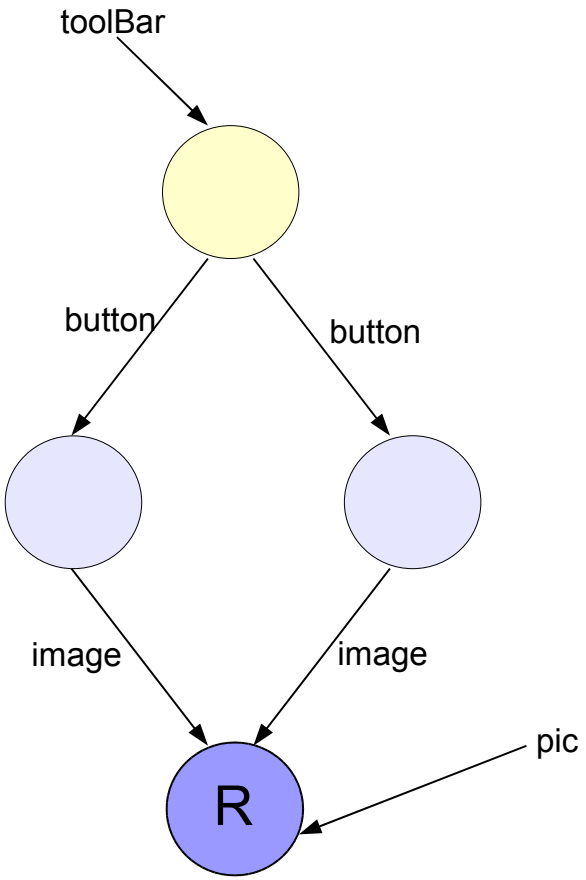

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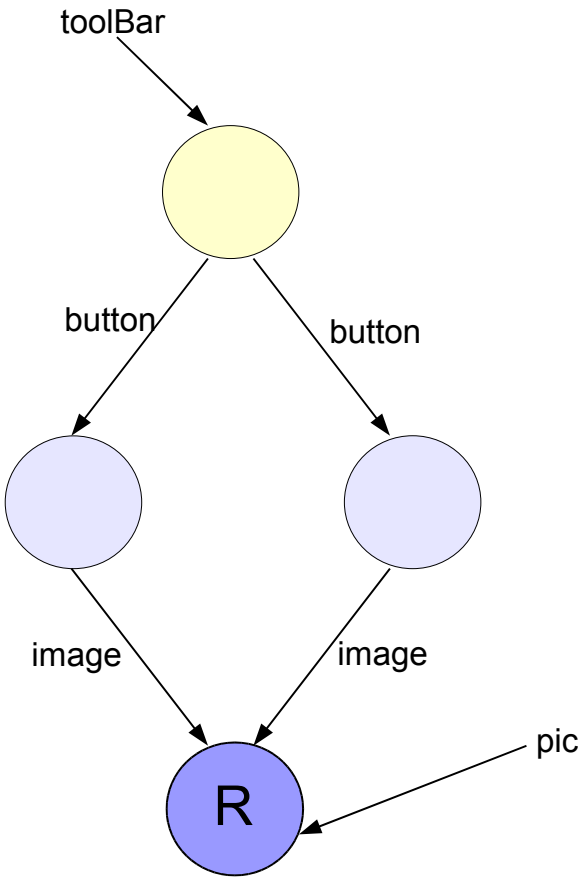

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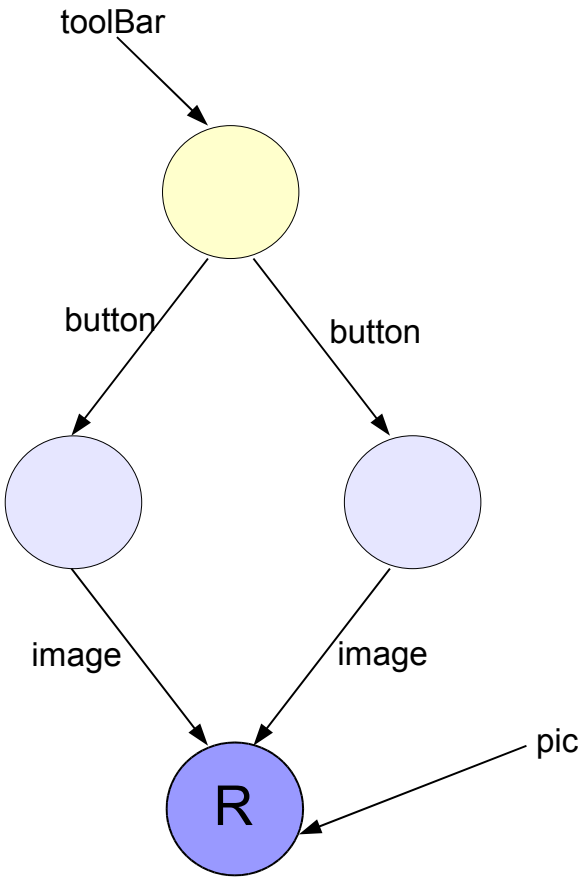

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- Dynamic Instrumentation:
  - Does not rely on modifying the JVM
  - A `Manager` class keeps dynamic interest counts
  - The modified source code calls static methods of the `Manager`
- CLOSER appears transparent to the programmer
  - The programmer can inspect and change the code instrumented by CLOSER

Case Study

- We applied CLOSER to automate resource management of an SWT Showcase Graphics Application

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- Manually removed all resource management code

Case Study, Continued

	Original	Instrumented
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# Strong Static Dispose	116	117
# Weak Static Dispose	14	63
# Dynamic Dispose	0	0
# Number of Resource Bugs	1	0
# Lines of Resource Mgmt Code	316	356
Resource Mgmt Code to Application Size Ratio	4.2%	4.9%

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- User annotates only 5 resources.
- CLOSER infers all the remaining 62 resources.

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- Missing dispose call in the original code was a resource leak.
- Programmer forgot to dispose a `Transpose` (resource in SWT).

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# Number of Resource Bugs	1	0
# Lines of Resource Mgmt Code	316	356
Resource Mgmt Code to Application Size Ratio	4.2%	4.9%

- More weak dispose calls because CLOSER is path-insensitive.
- Inserts redundant null-checks even though one already exists.

Case Study, Continued

```
private void paint() {
    if(image == null) {
        if(image!=null){
            image.dispose();
        }
        image = new Image(...);
    }
}
```

Case Study, Continued

	Original	Instrumented
# Resources	67	67
# Strong Static Dispose	116	117
# Weak Static Dispose	14	63
# Dynamic Dispose	0	0
# Number of Resource Bugs	1	0
# Lines of Resource Mgmt Code	316	356
Resource Mgmt Code to Application Size Ratio	4.2%	4.9%

- No shared resources in the application.
- CLOSER successfully identified all resources as unshared.

Case Study, Continued

	Original	Instrumented
# Resources	67	67
# Strong Static Dispose	116	117
# Weak Static Dispose	14	63
# Dynamic Dispose	0	0
# Number of Resource Bugs	1	0
# Lines of Resource Mgmt Code	316	356
Resource Mgmt Code to Application Size Ratio	4.2%	4.9%

- CLOSER doesn't cause code bloat or substantial runtime overhead.
- And it is correct by construction.

Related Work

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A practical flow-sensitive and context-sensitive c and c++ memory leak detector.
In *PLDI '03: Proceedings of the ACM SIGPLAN 2003 conference on Programming language design and implementation* (New York, NY, USA, 2003), ACM, pp. 168–181.

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