Debug All Your Code: Portable Mixed-Environment Debugging

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Martin Hirzel
Robert Grimm
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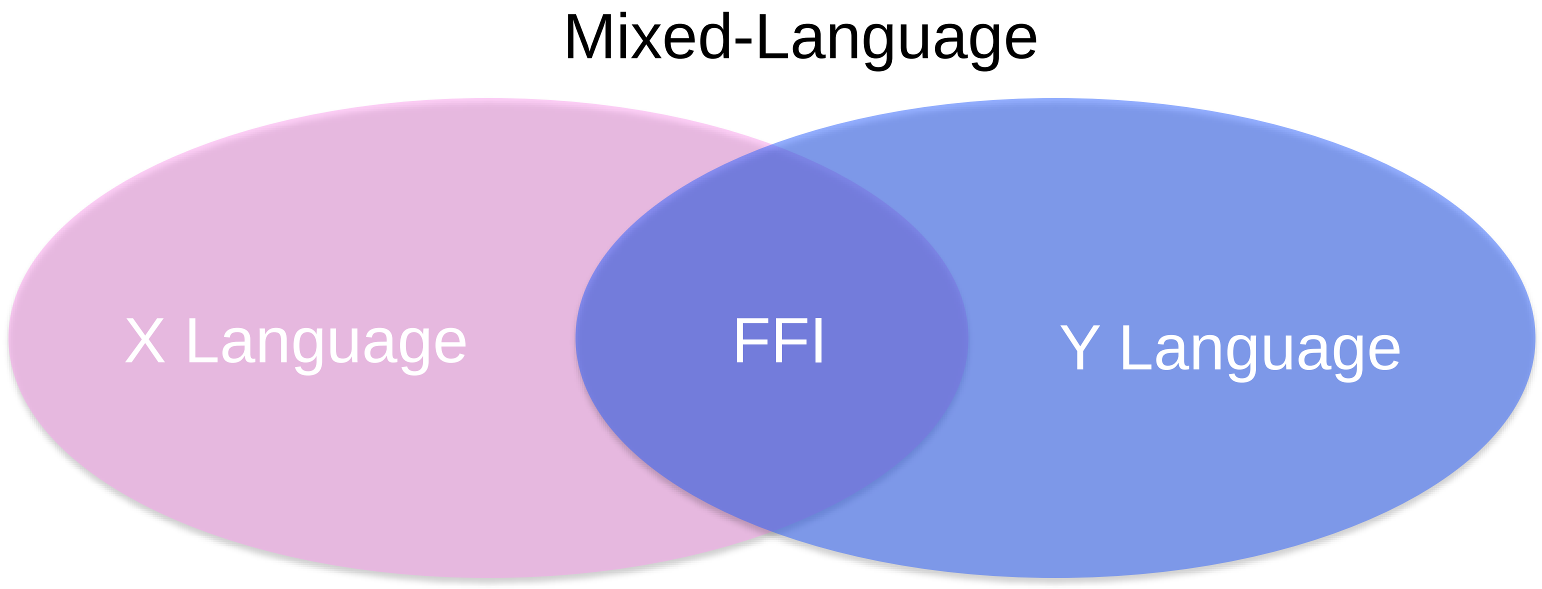
Portable mixed-environment debugging

Programmers build systems in multiple languages.

1. Leverage legacy code and existing libraries.
2. Match language features to a task.



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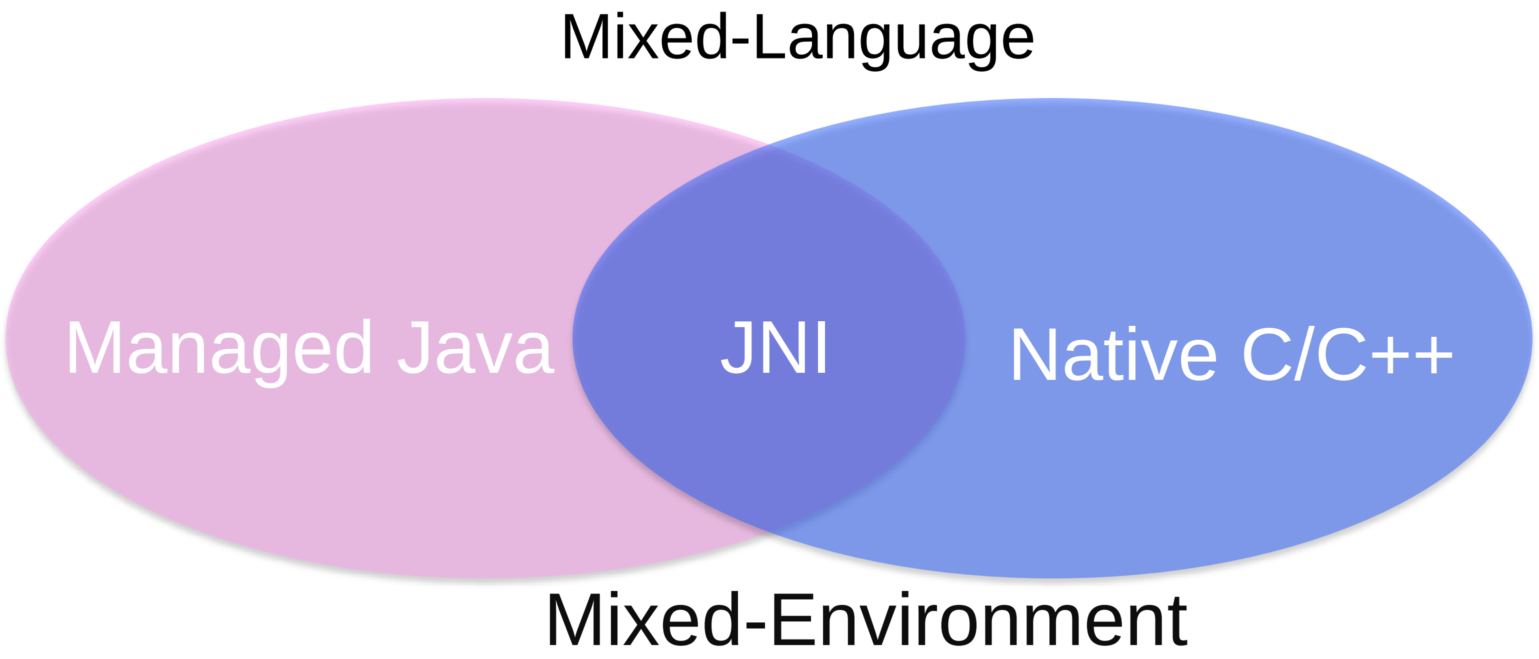
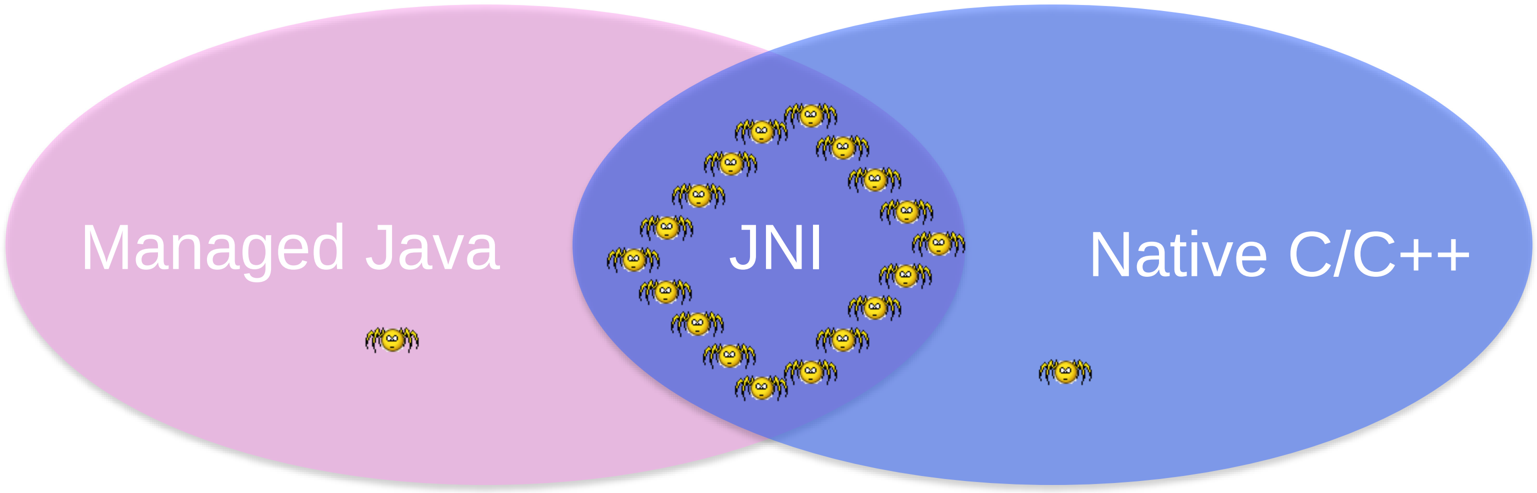


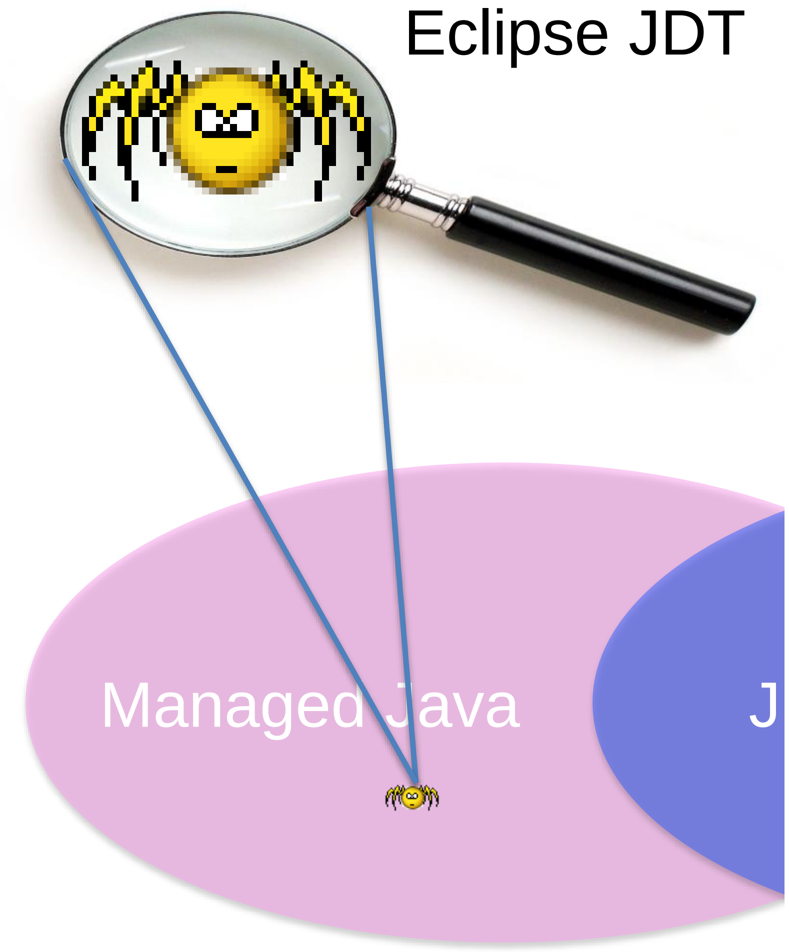
The problem

Bugs appear in all your code!



Mixed-Environment

The problem with single-environment debugging



Mixed-Environment

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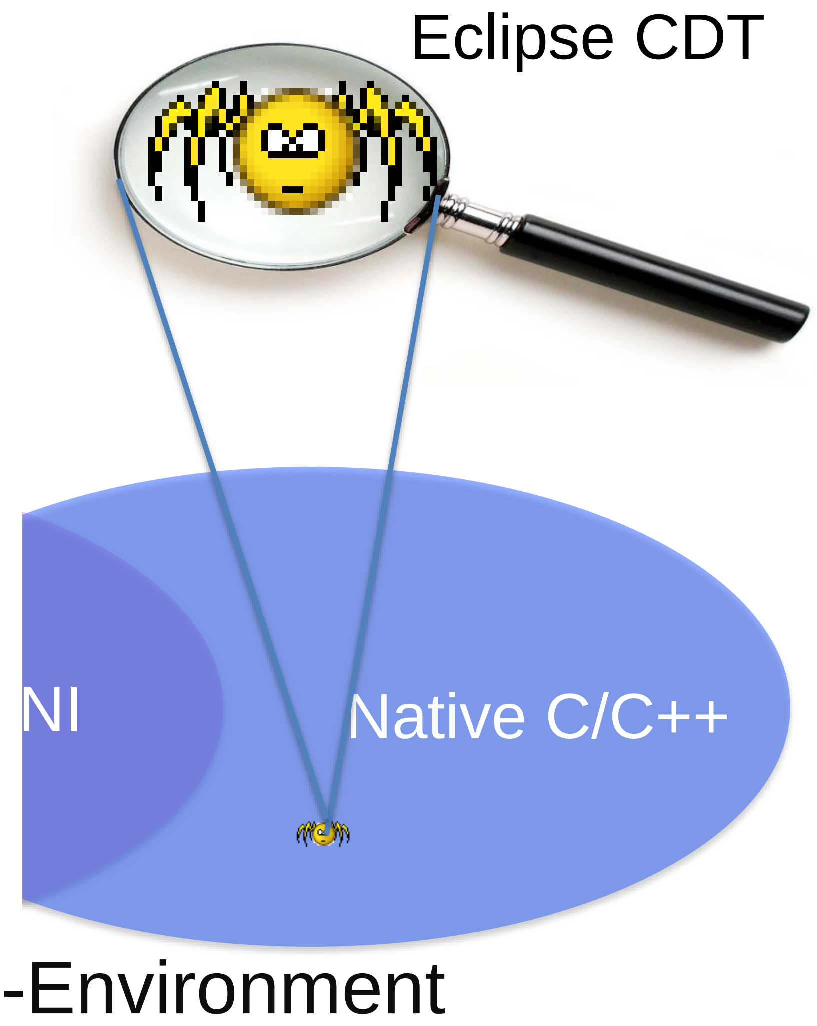
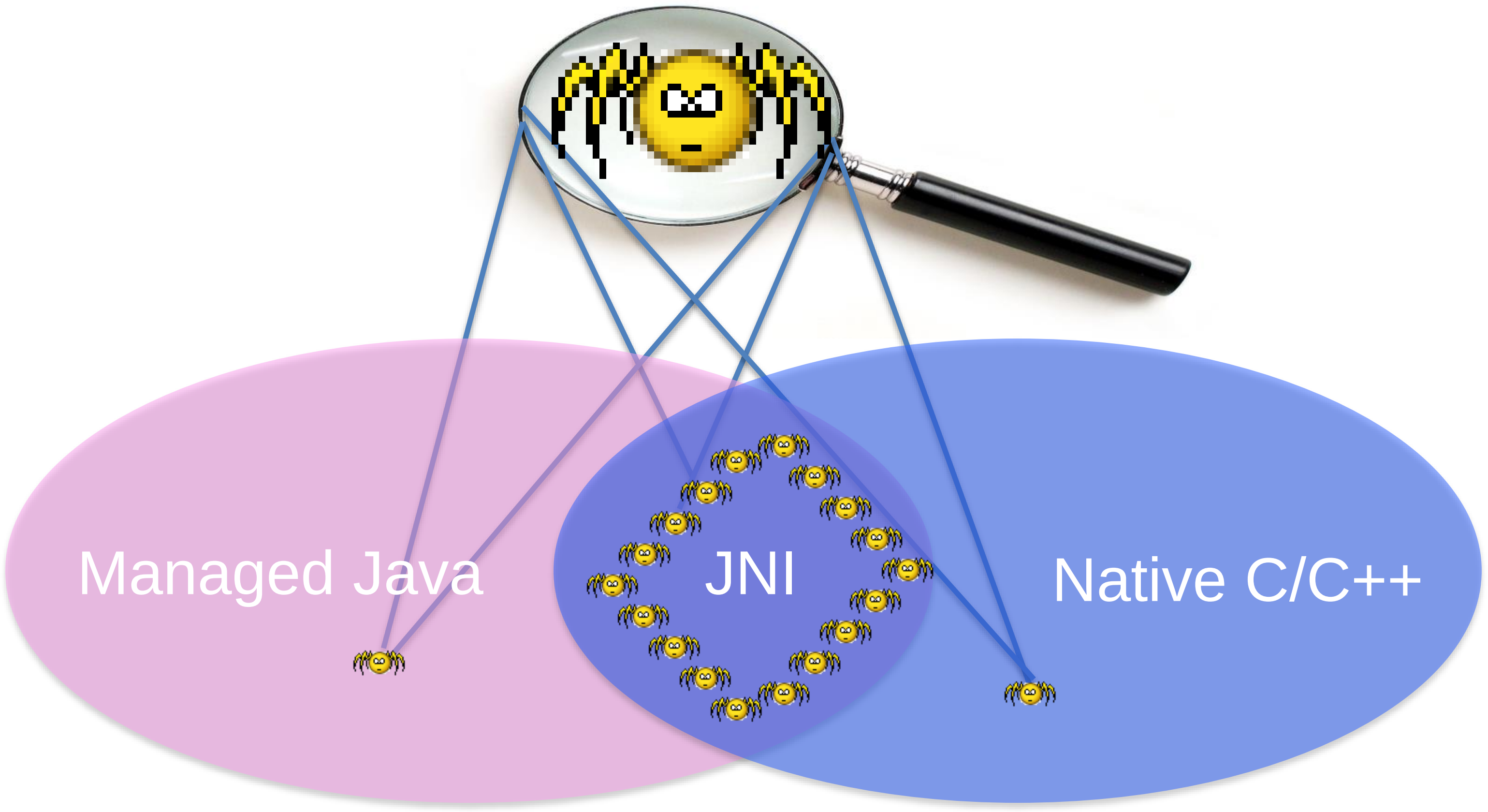


Our goal

Portable mixed-environment debugging



Mixed-Environment

Our contribution and results

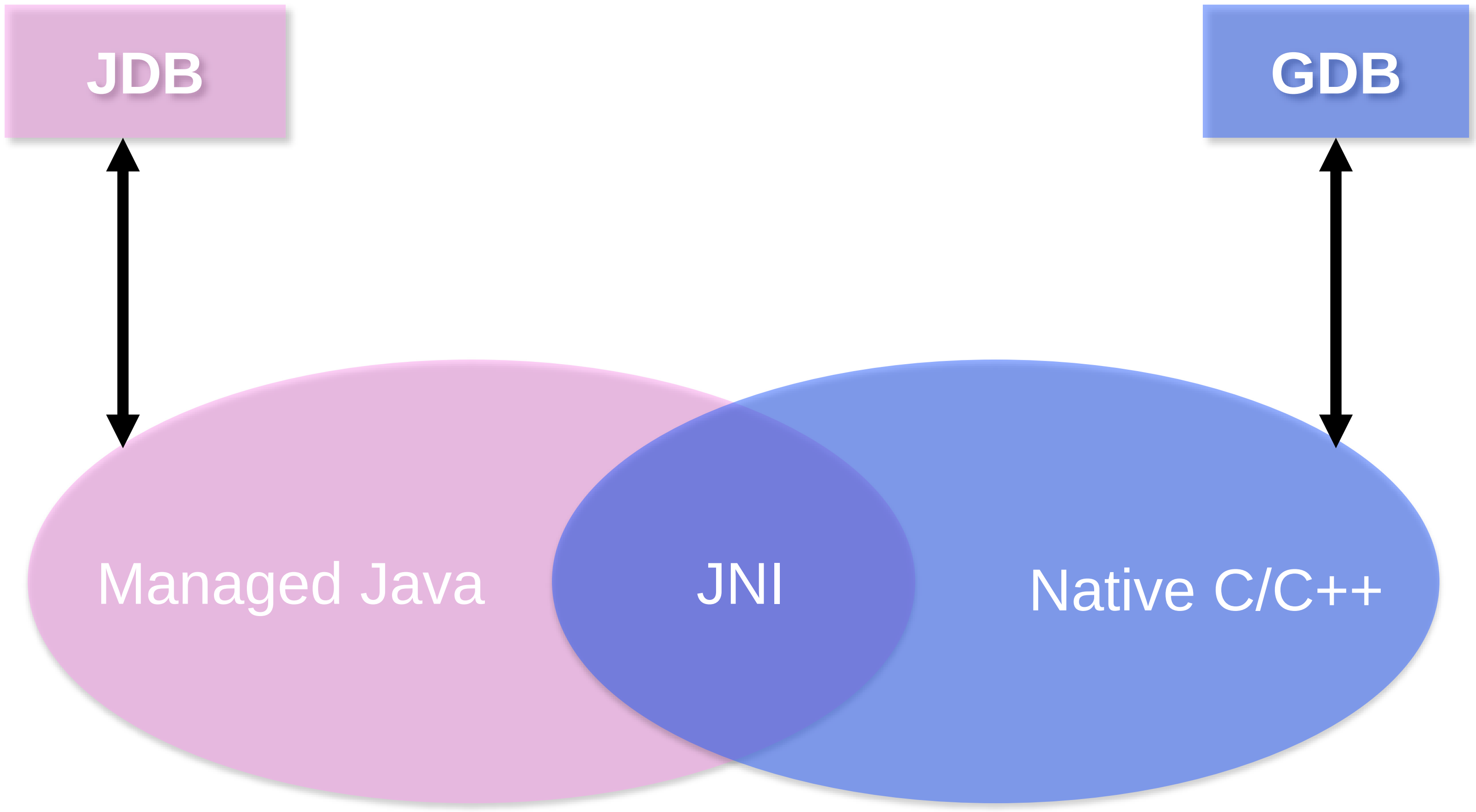
Composition

1. Add an intermediate agent.
2. Attach single-environment debuggers.
3. Dispatch debuggers dynamically.

Blink results

1. **Simple**: Add 10 K SLOC of new code.
2. **Portable**: Support Linux, Windows, Hotspot, J9, GCC, Microsoft C++.
3. **Powerful**: Catch FFI bugs.

Problem: GDB does not work at a Java breakpoint.



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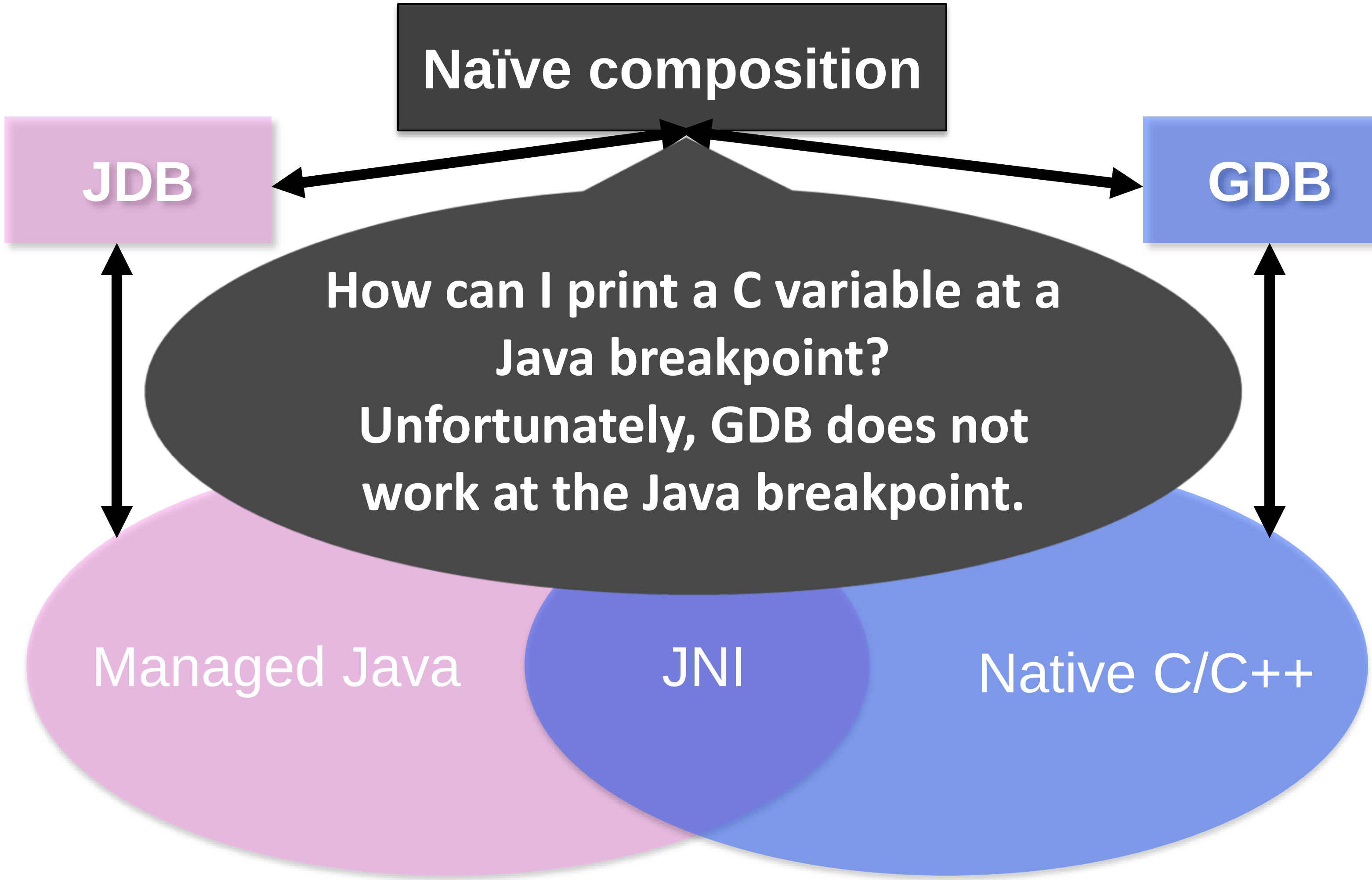
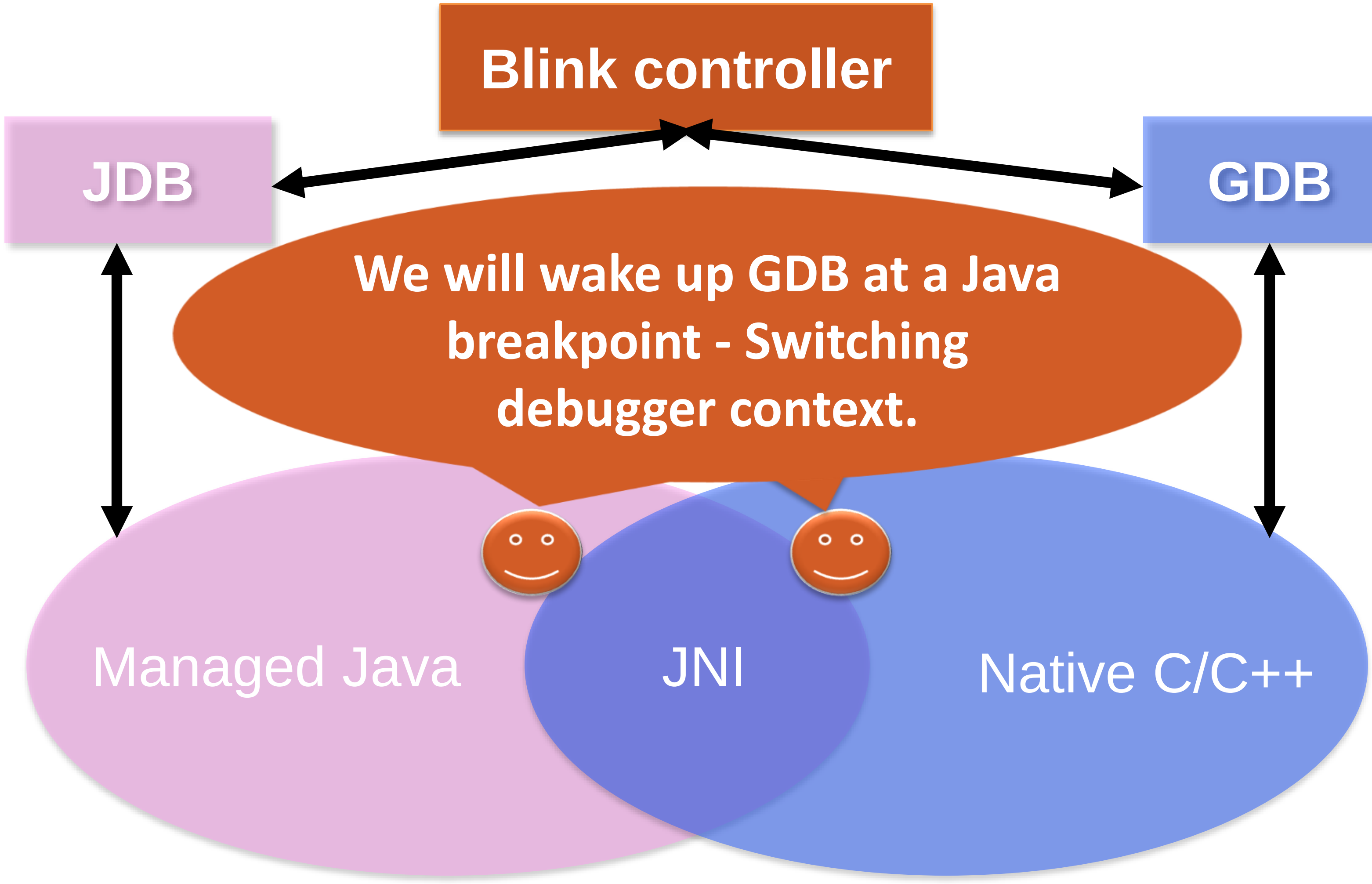
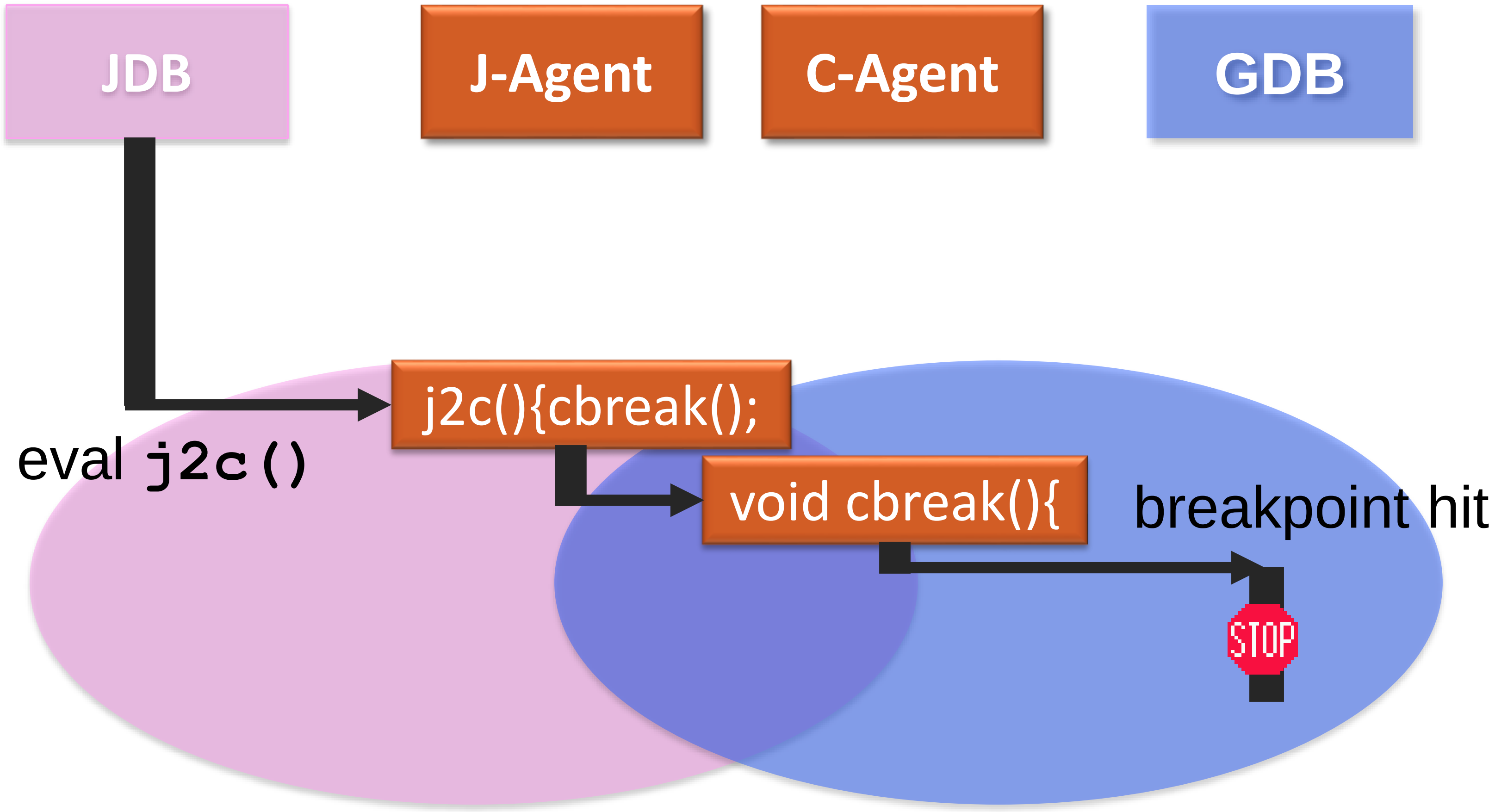


How can I print a C variable at a Java breakpoint?
Unfortunately, GDB does not work at the Java breakpoint.

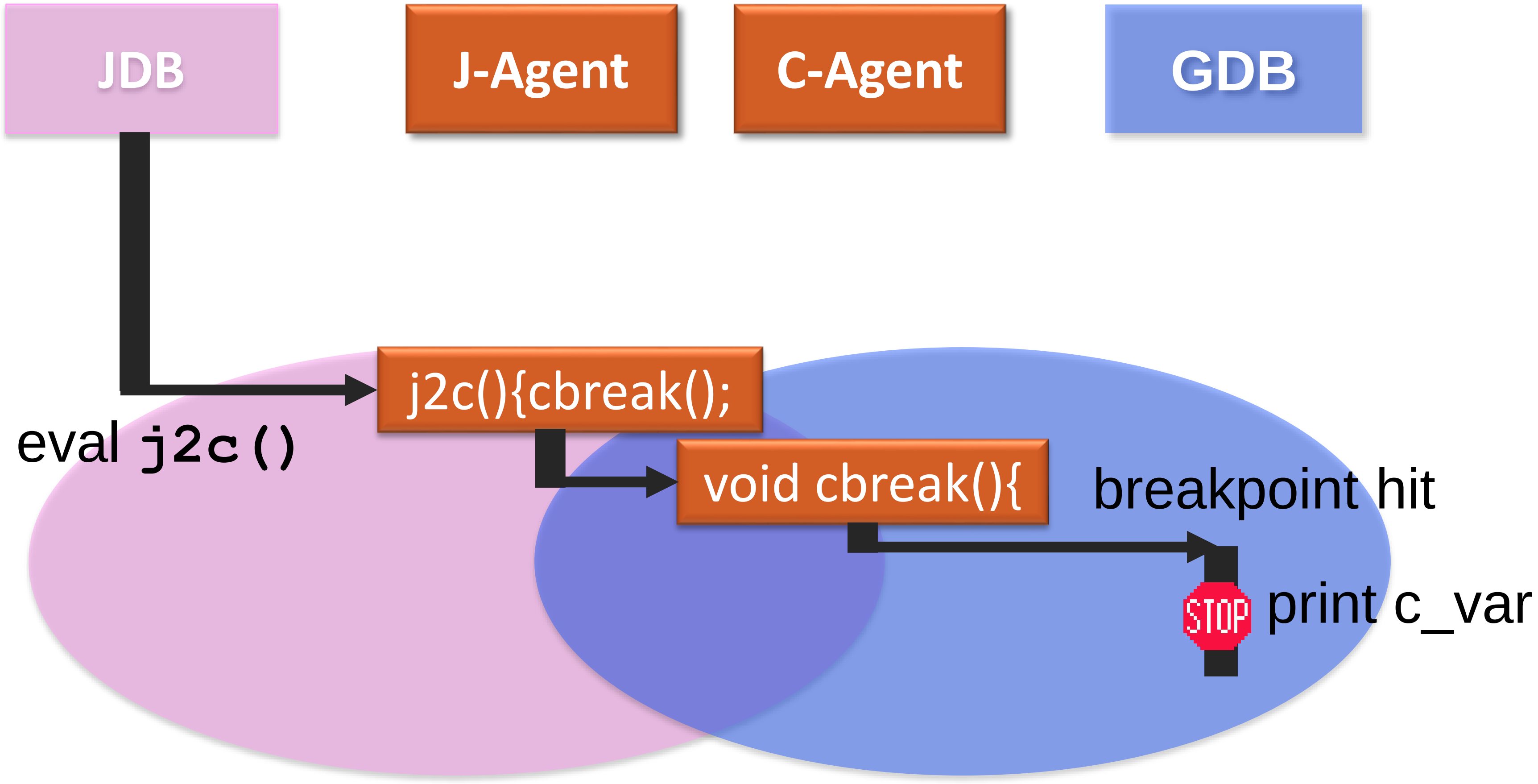
Our solution: the intermediate agent switches debugger context.


Blink controller
JDB
GDB
We will wake up GDB at a Java breakpoint - Switching debugger context.
Managed Java
JNI
Native C/C++

Our solution: switch debugger context from Java to C.



Our solution: switch debugger context from Java to C.



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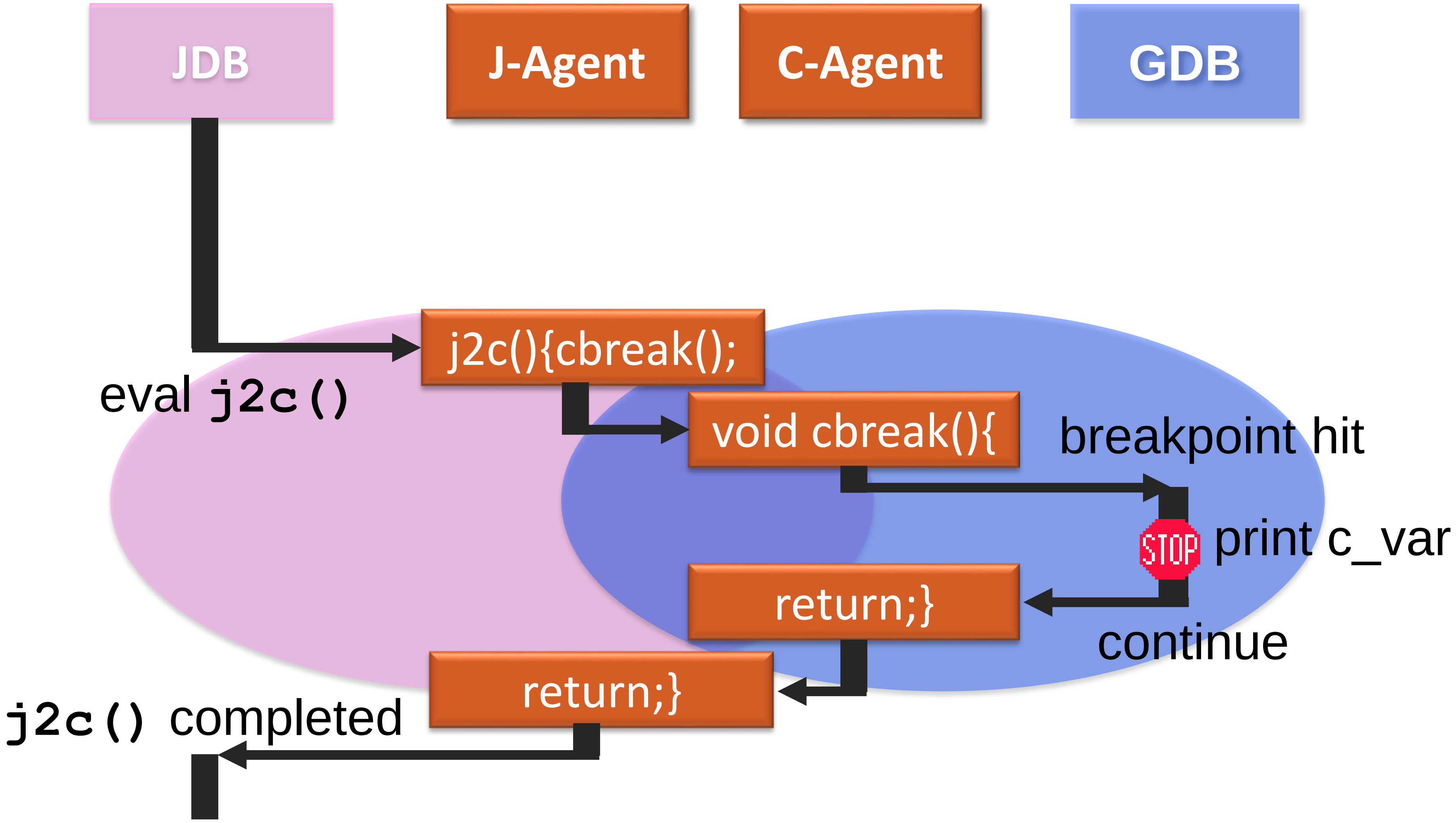
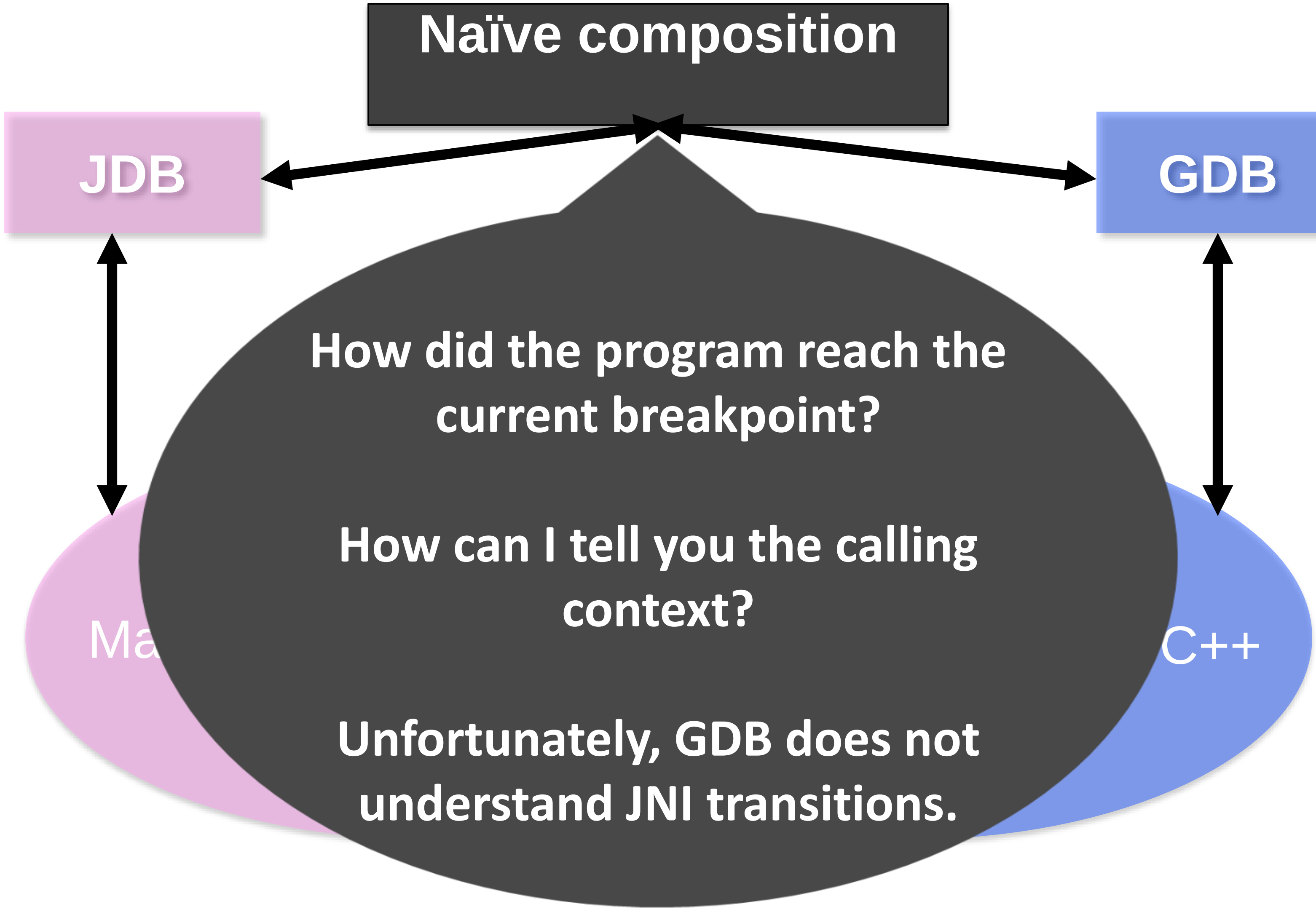


Problem: GDB does not understand JNI calling conventions.

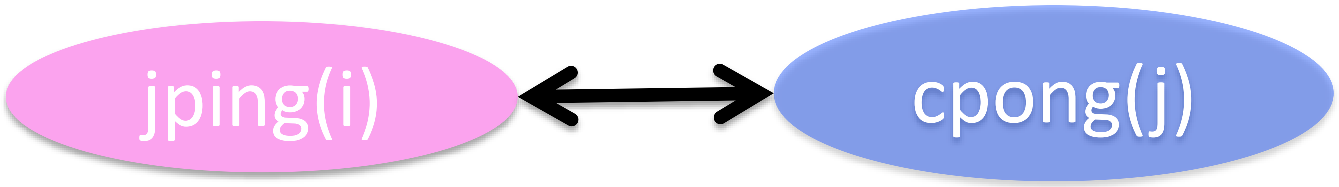


How did the program reach the current breakpoint?

How can I tell you the calling context?

Unfortunately, GDB does not understand JNI transitions.

Problem: GDB does not understand JNI calling conventions.



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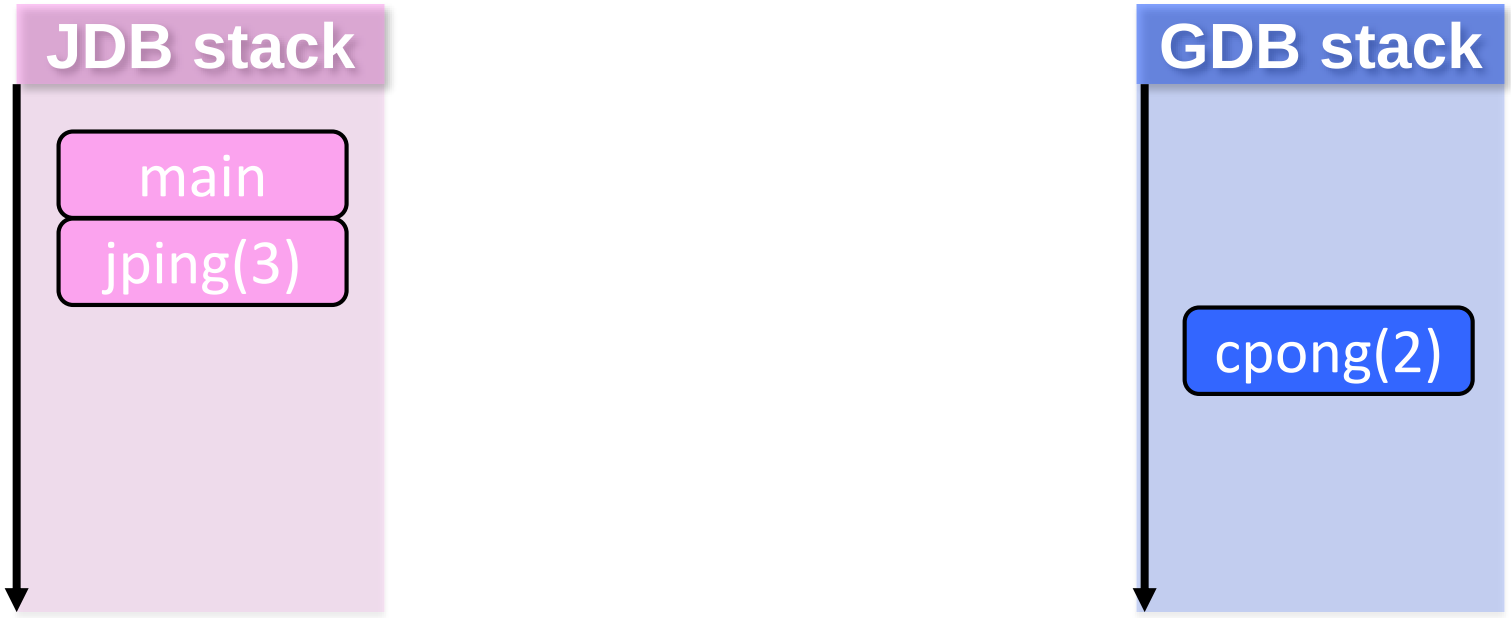

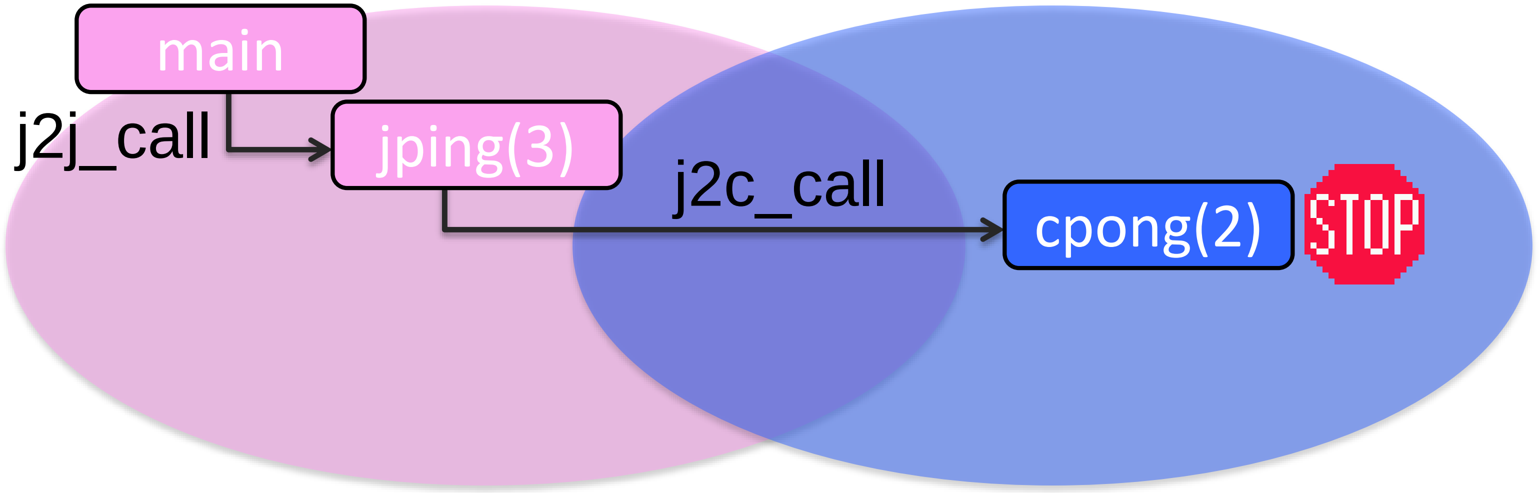

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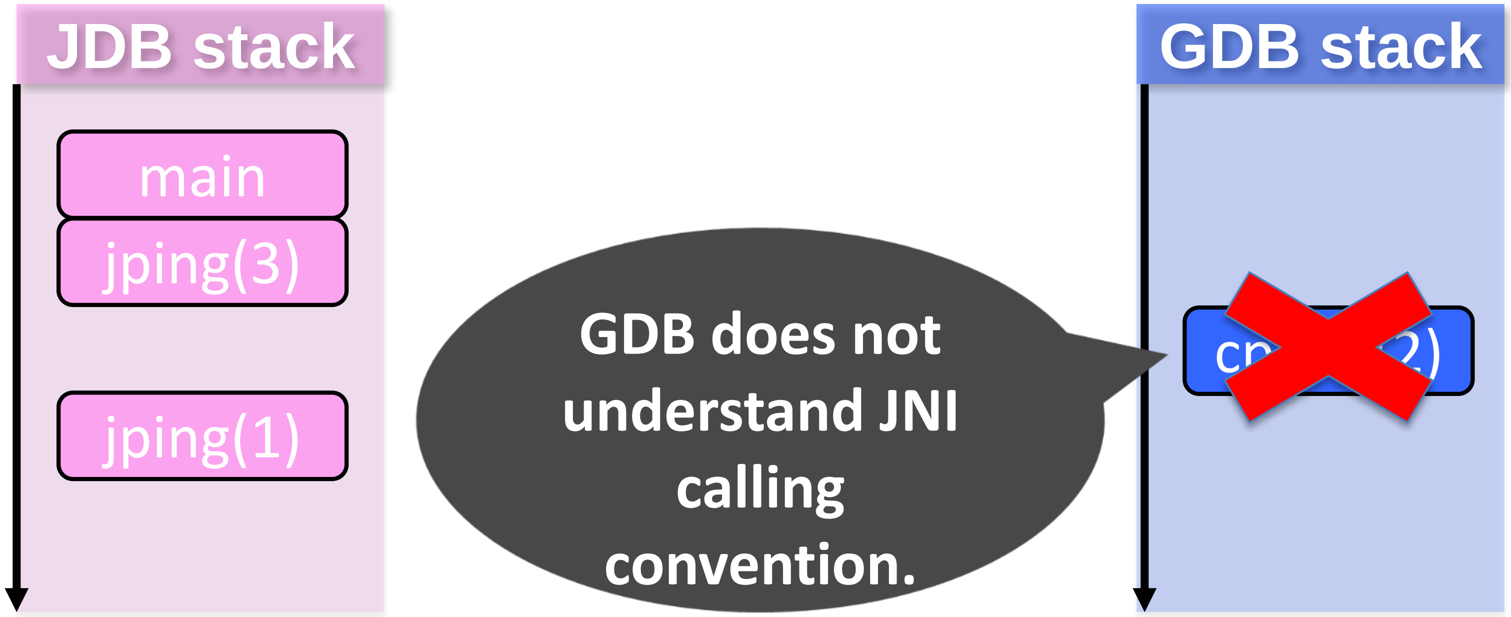

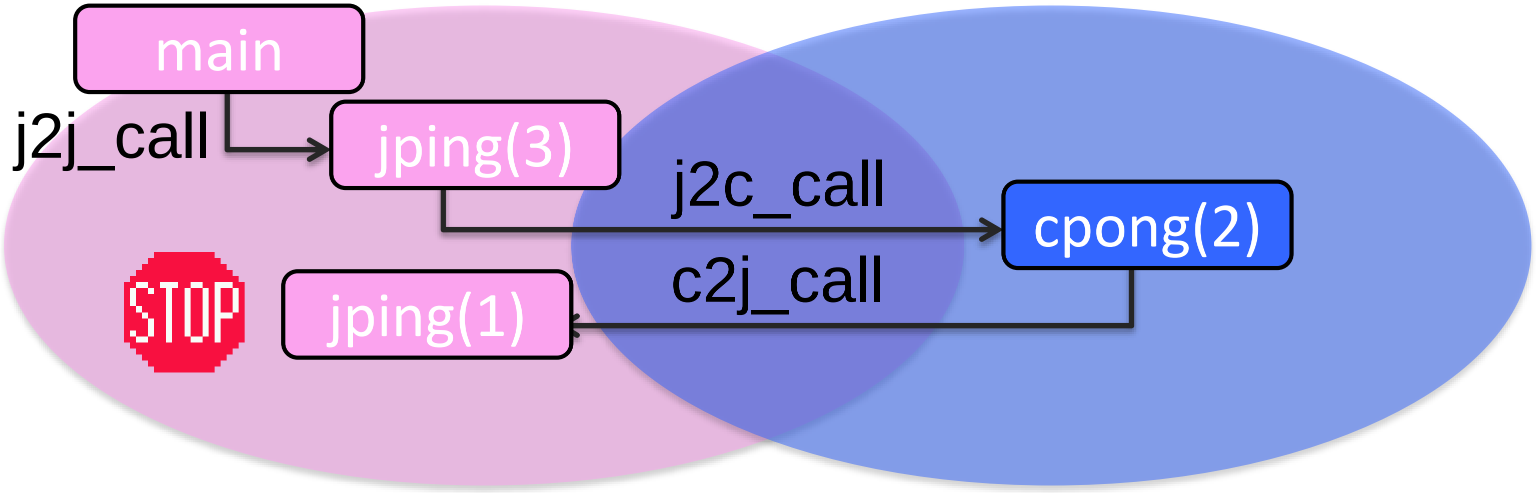

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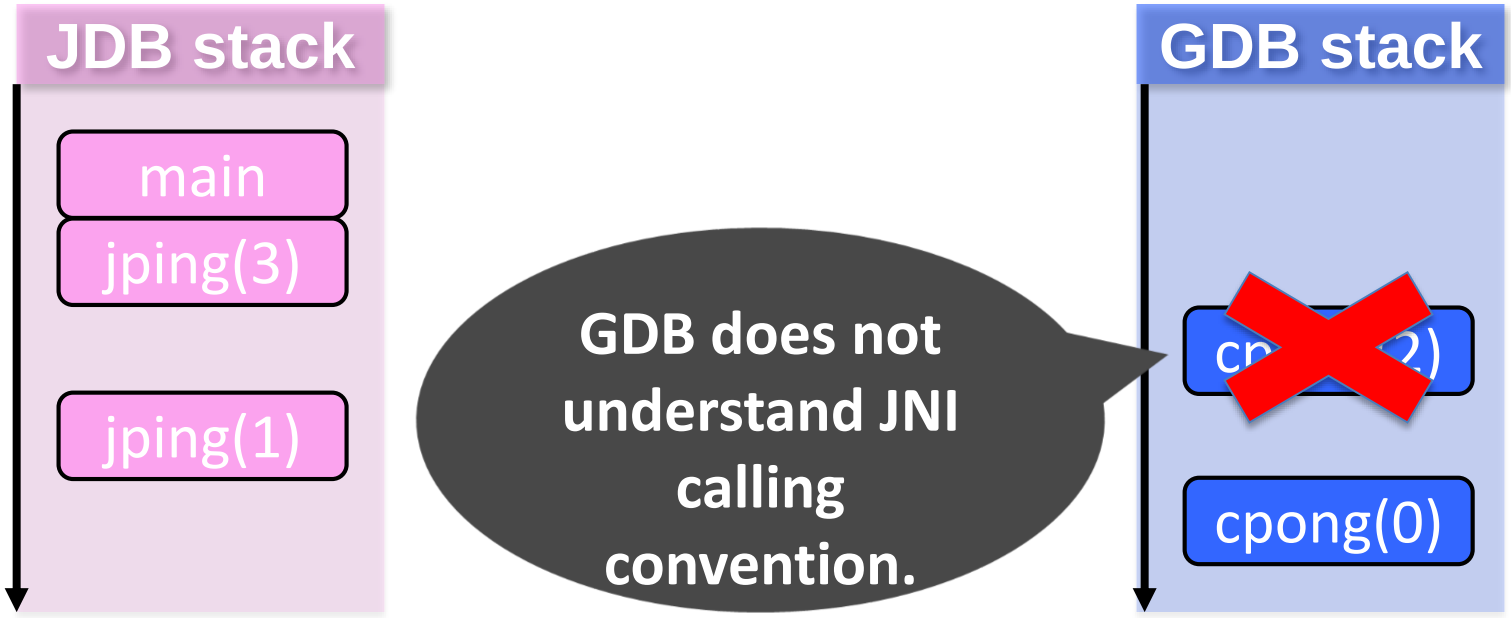
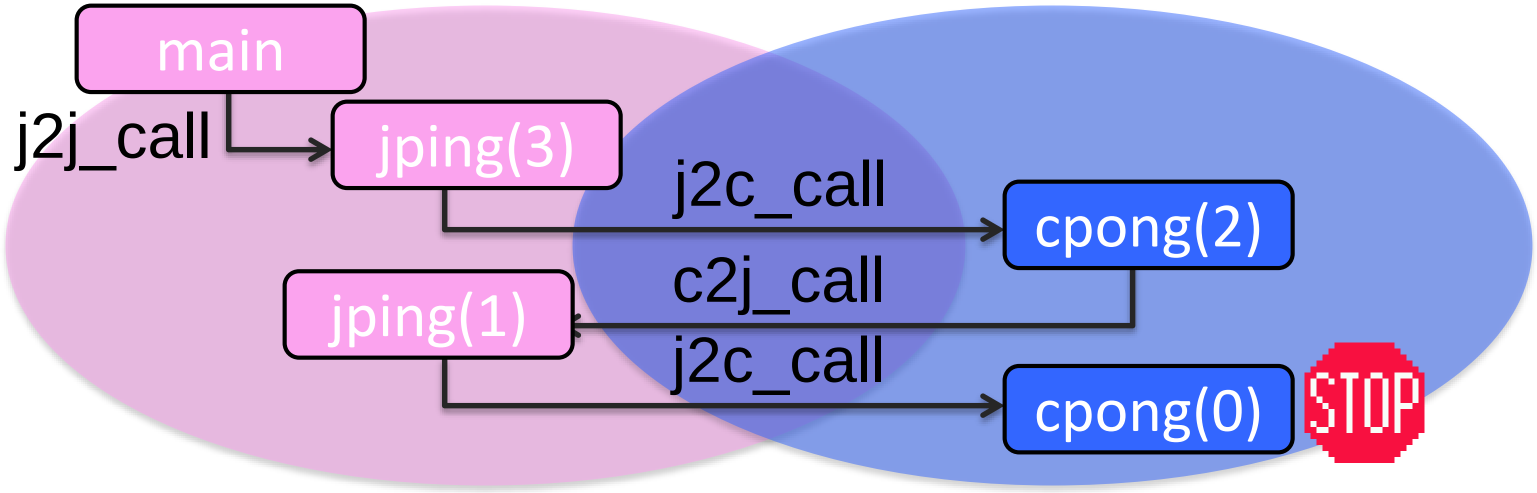
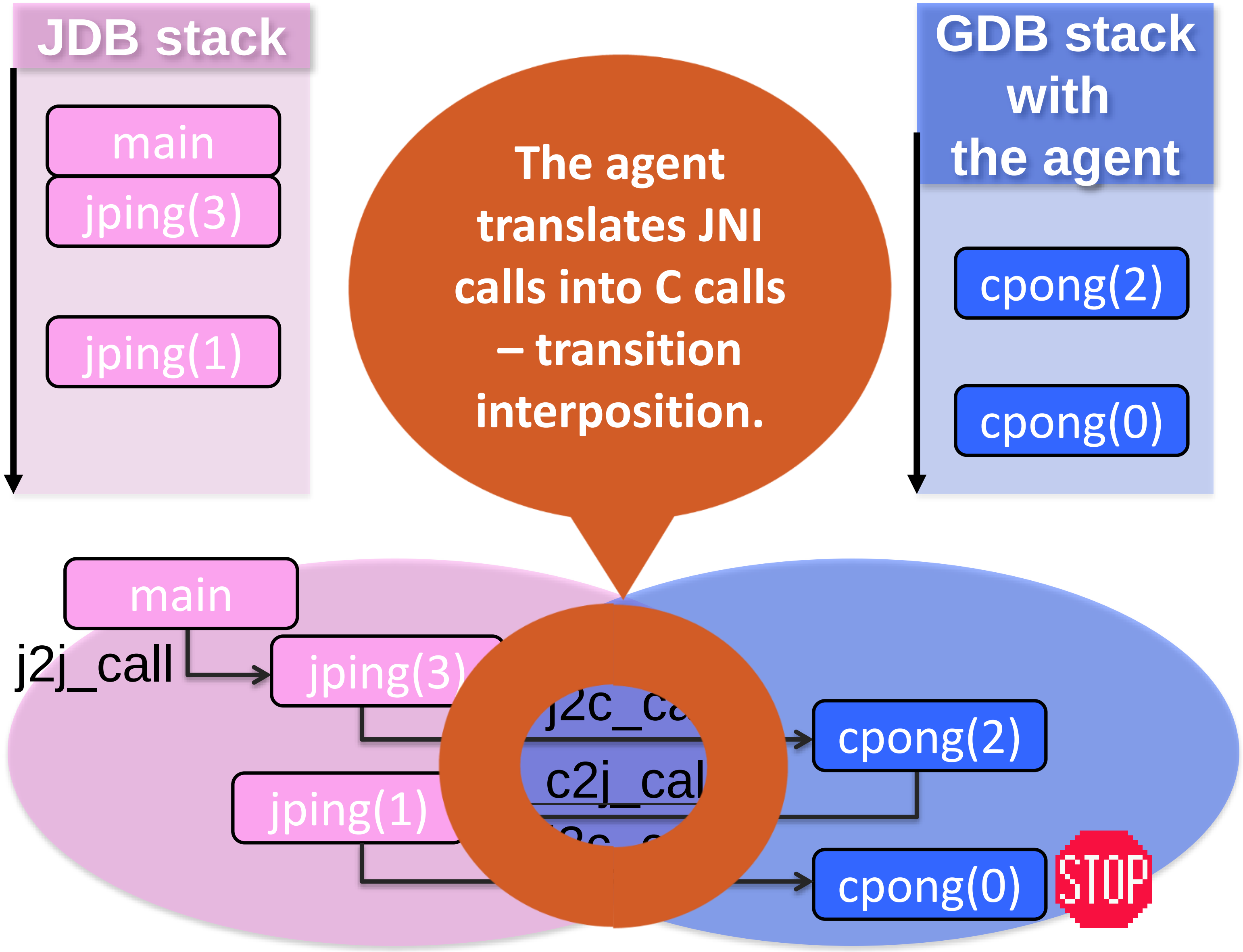
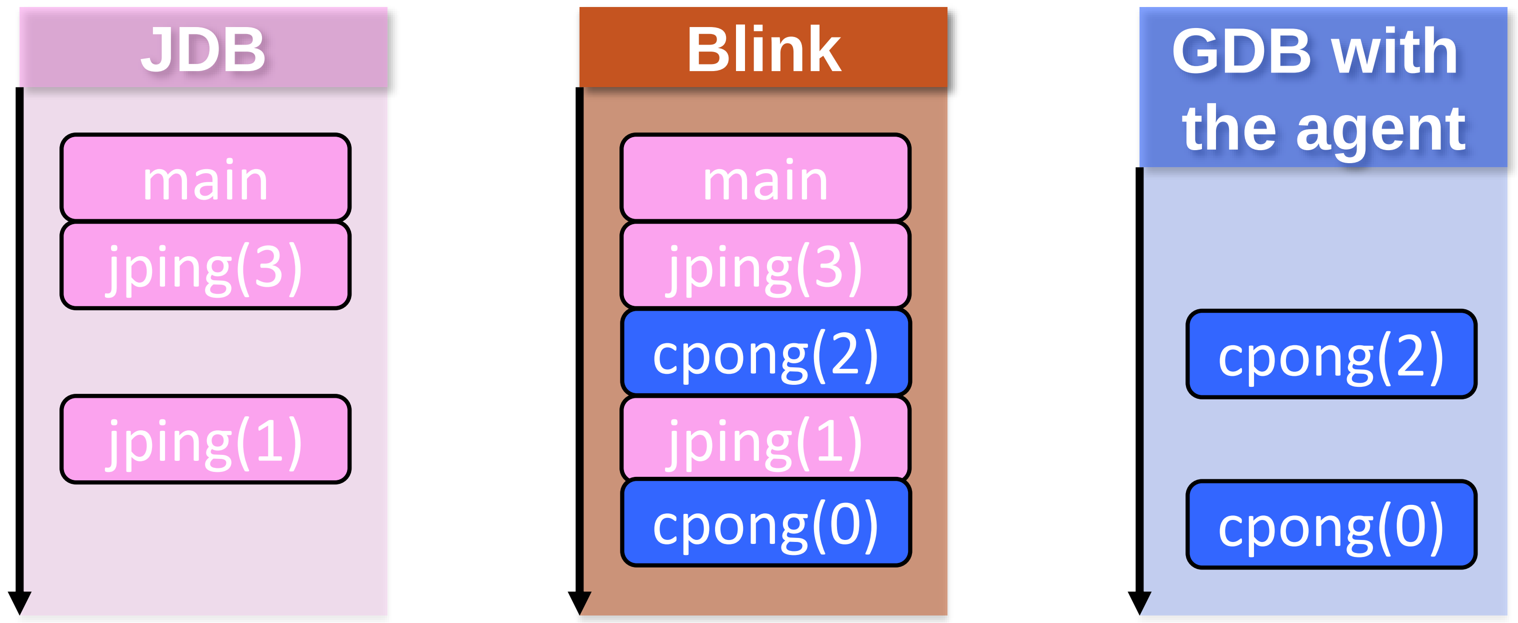


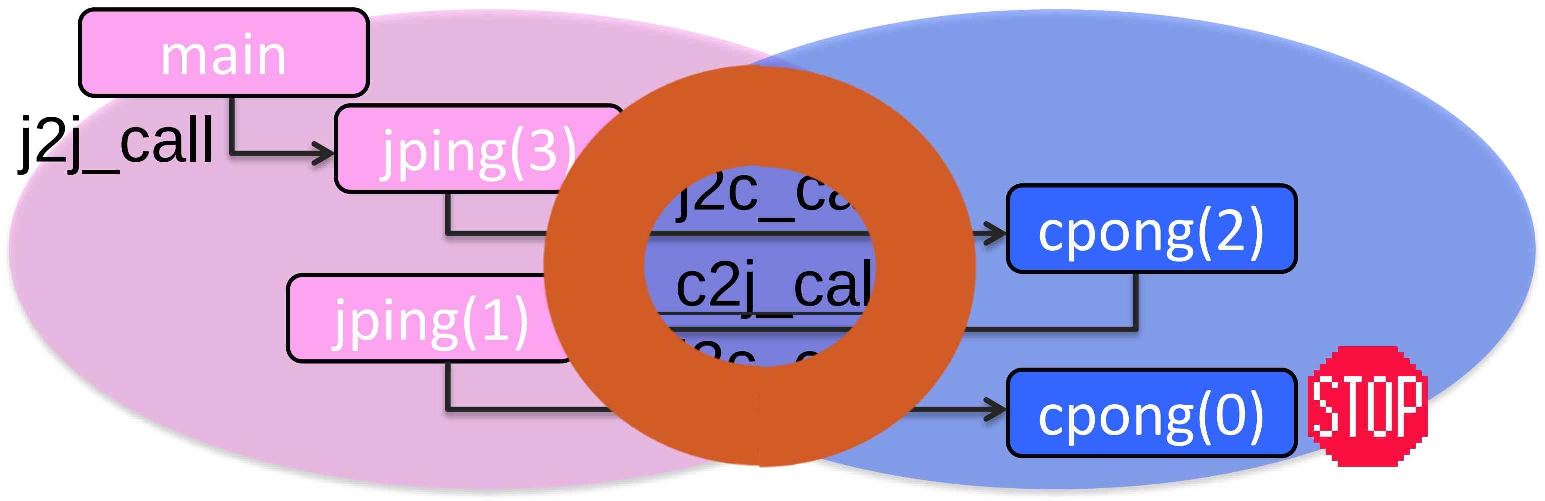


Our solution: translate JNI transitions into C transitions.

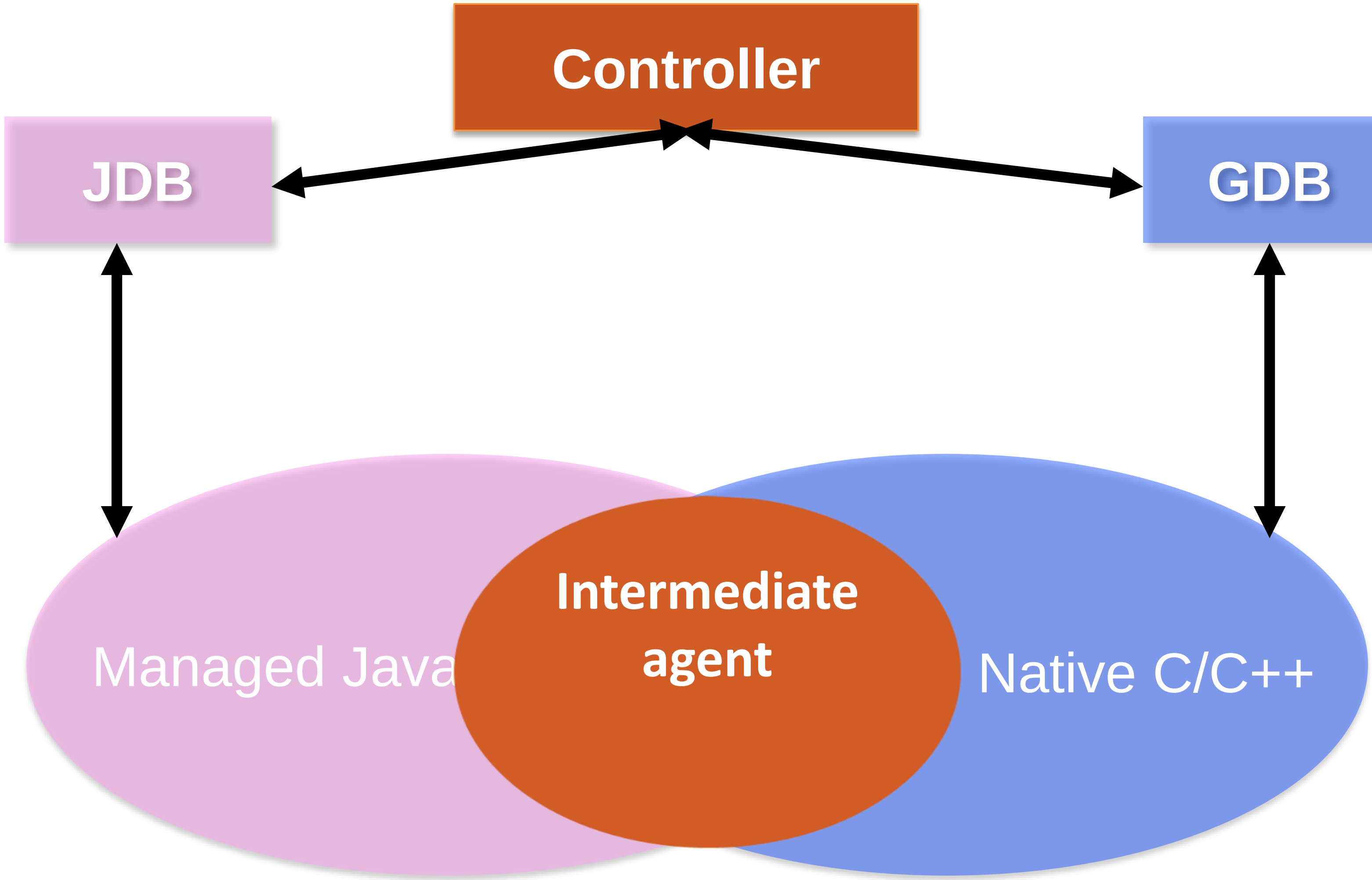


Our solution: compose a calling context.





Our solution: controller and intermediate agent

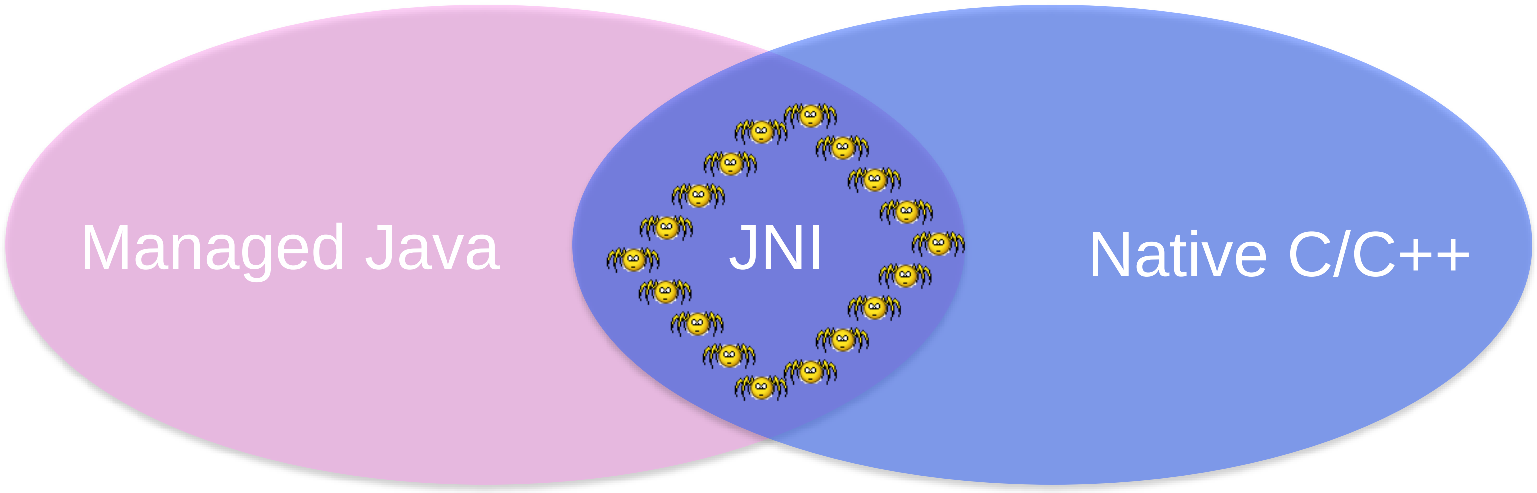


Outline

I. Problem
II. Debugger composition
    A. Switching debugger context
    B. Interposing transitions
→ III. Advanced features
    A. Evaluating Jeannie mixed-environment expressions
    B. Detecting FFI bugs
IV. Evaluation

Debugging boundary code

What do I need to debug boundary code?

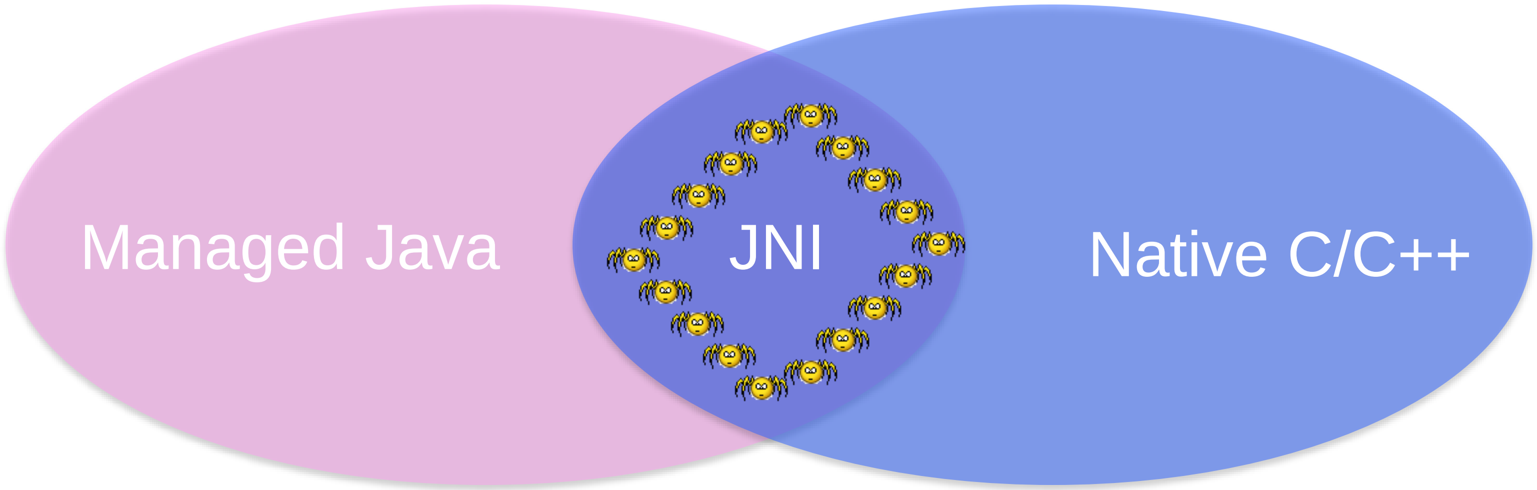


Mixed-Environment

Advanced features to debug boundary code

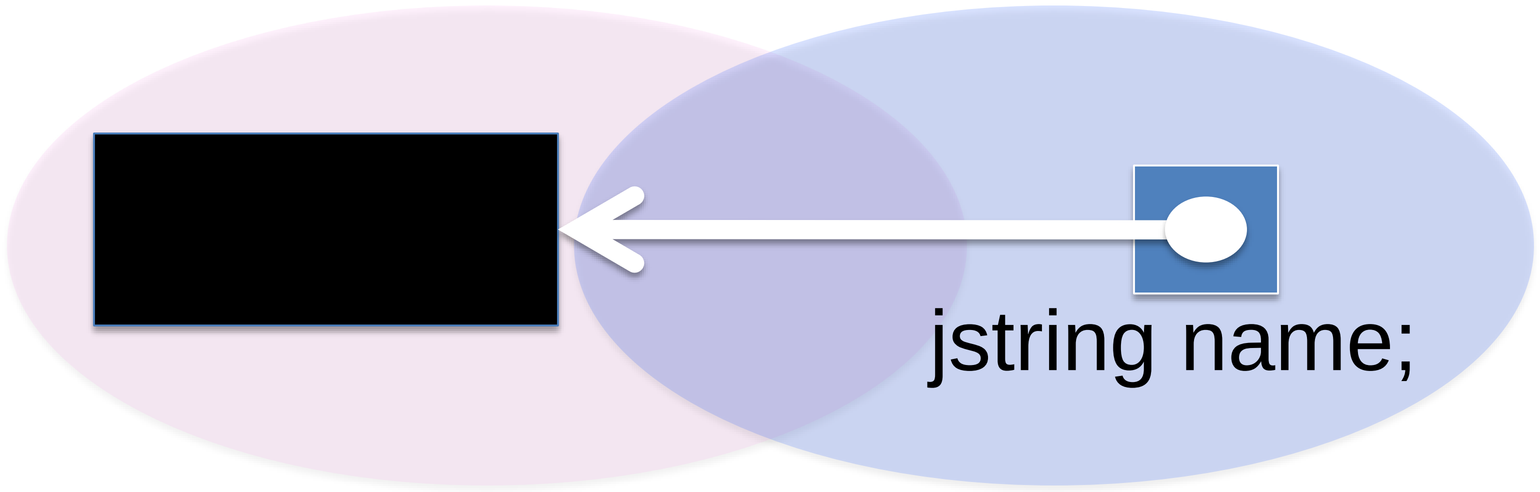
1. Evaluating Jeannie Expressions

2. Detecting FFI bugs



Mixed-Environment

Problem: you can not de-reference opaque pointers in C.



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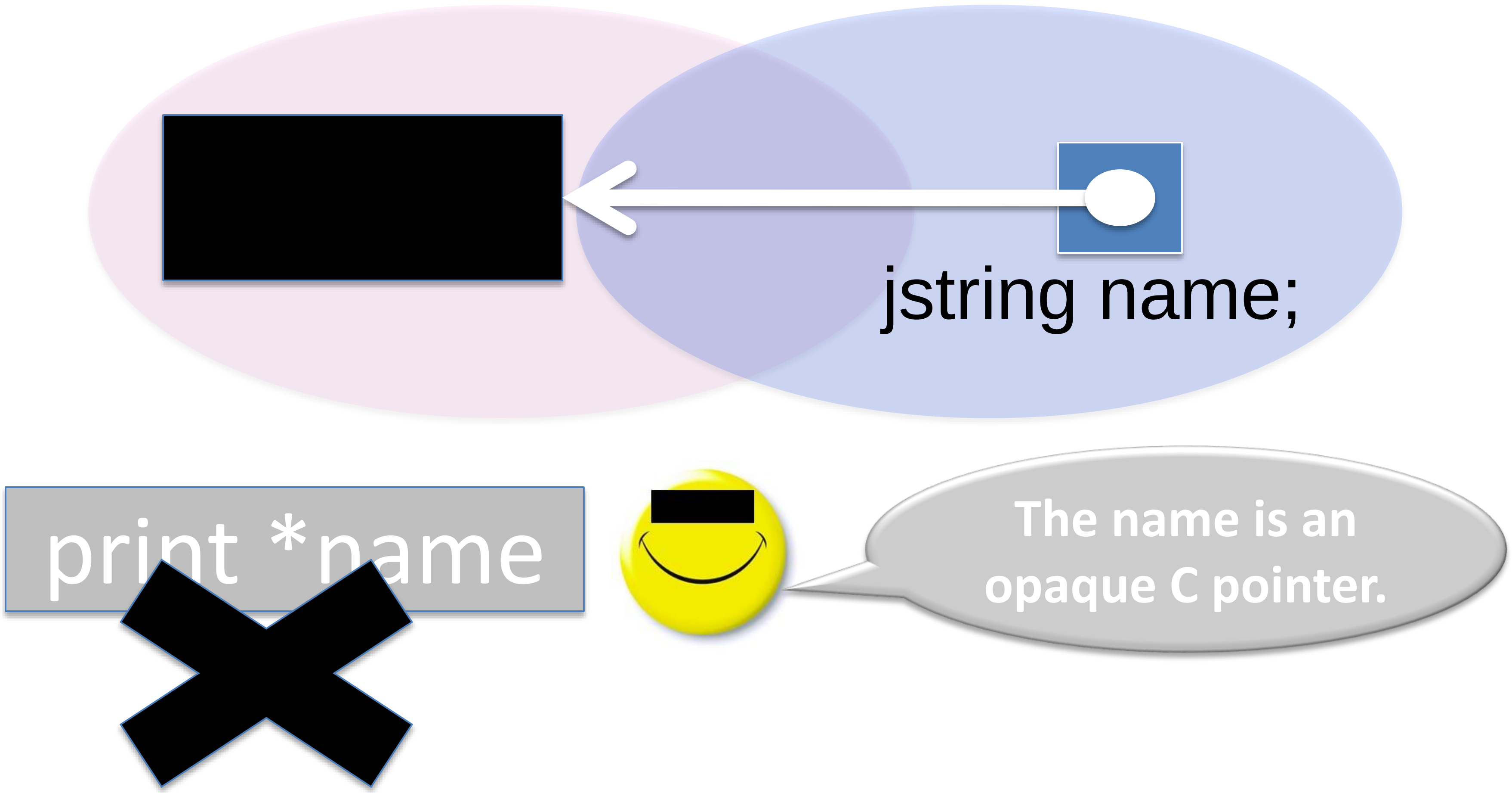
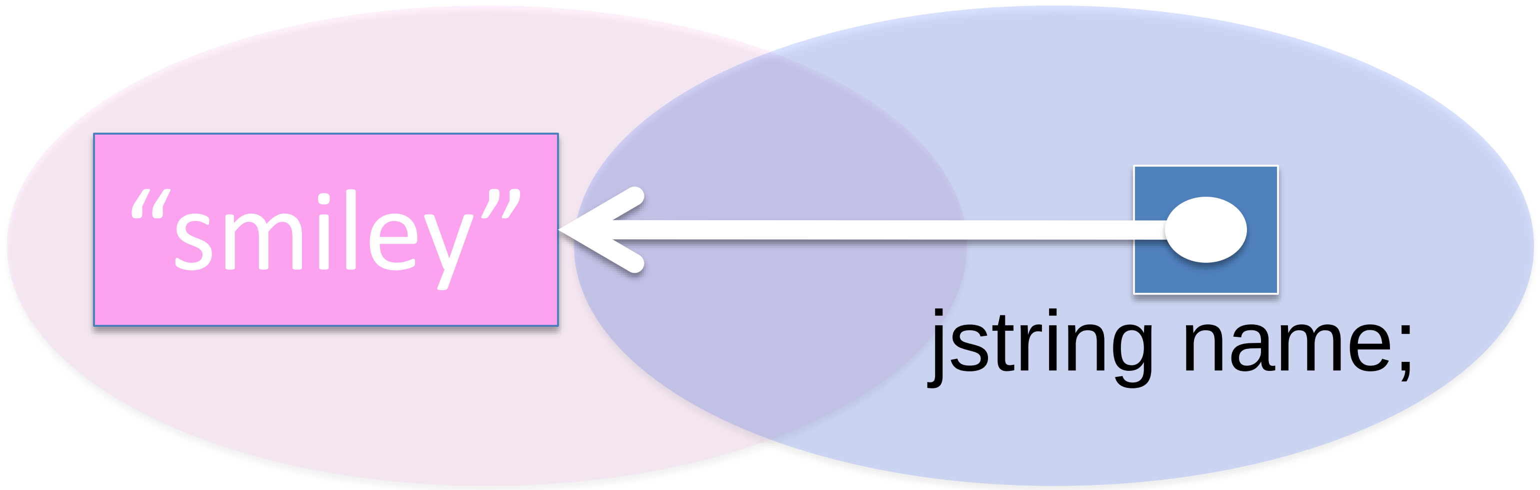
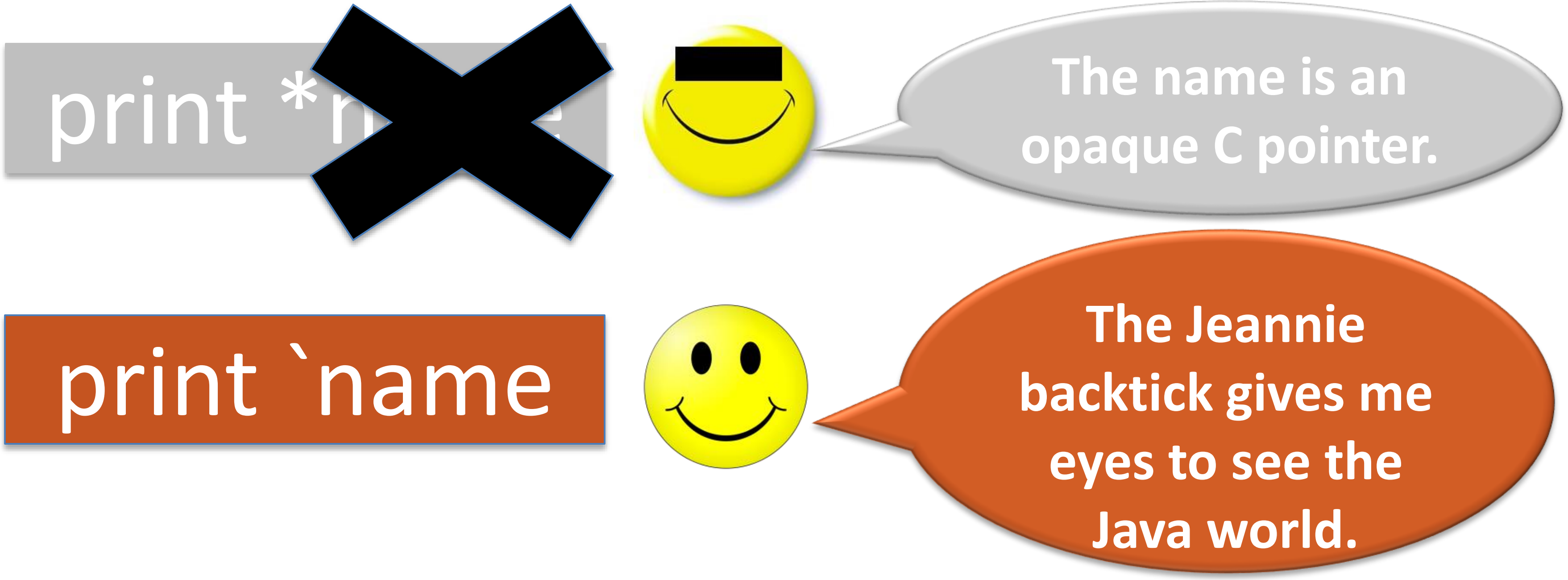
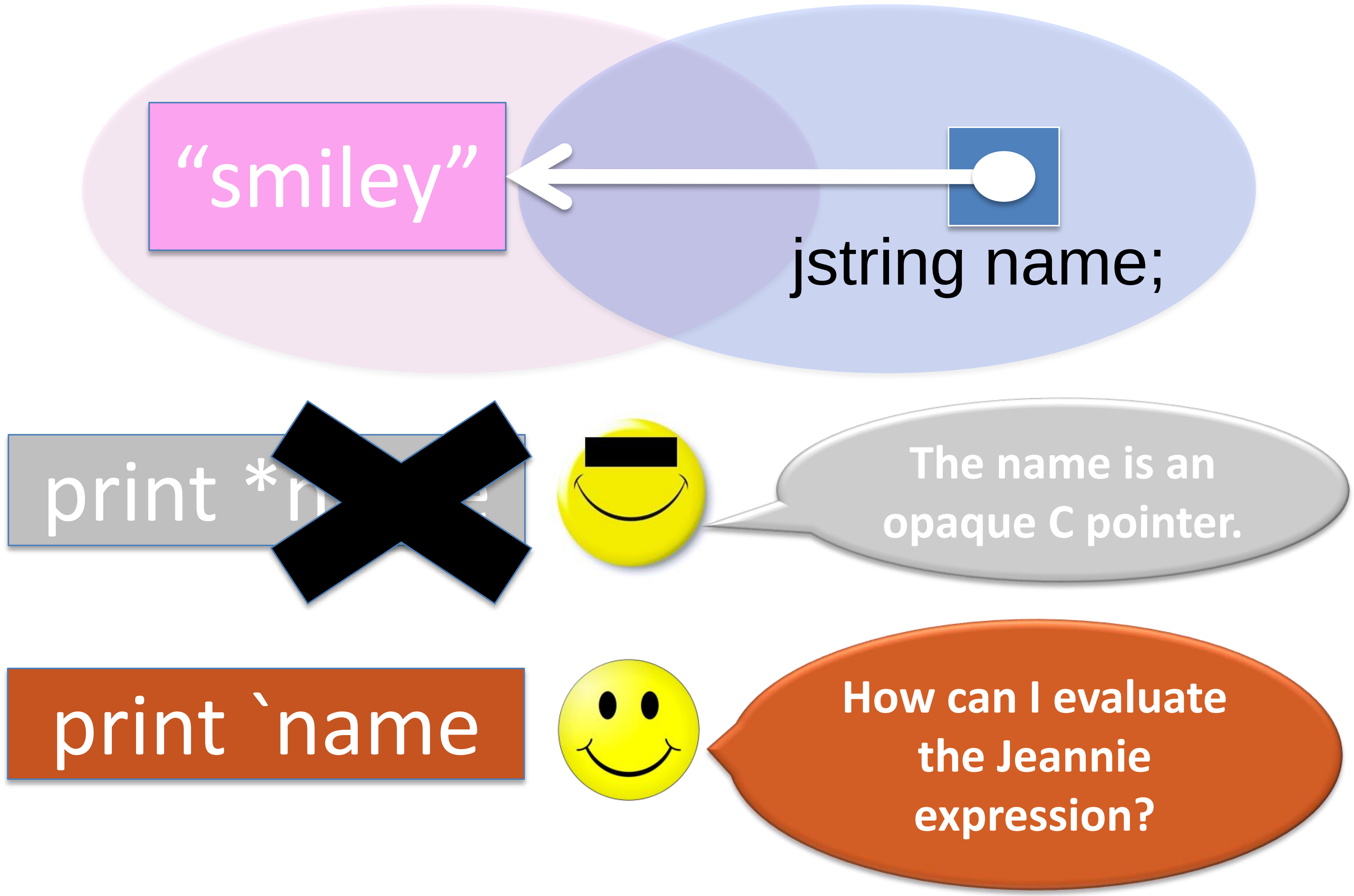


Our solution: use Jeannie expression



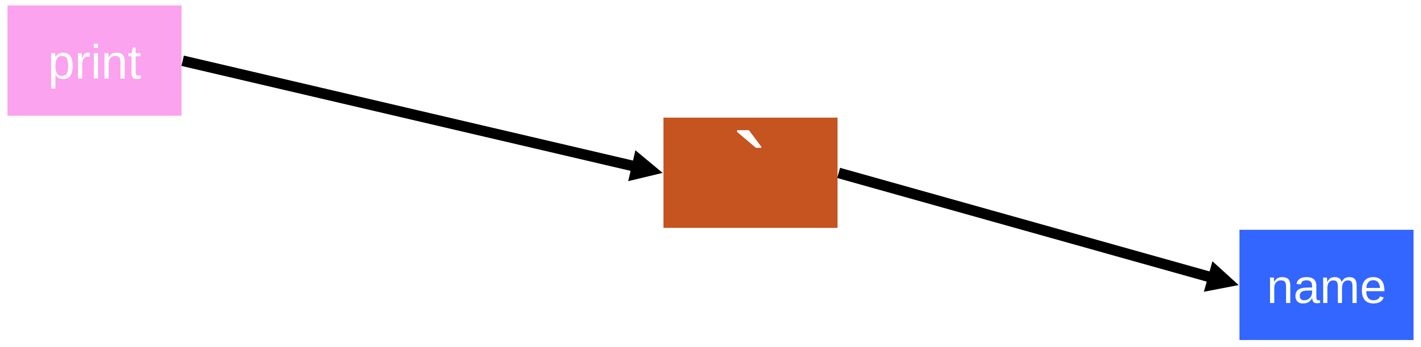

~~print *n e~~
The name is an opaque C pointer.
print `name
The Jeannie backtick gives me eyes to see the Java world.

Our solution: use Jeannie expression.

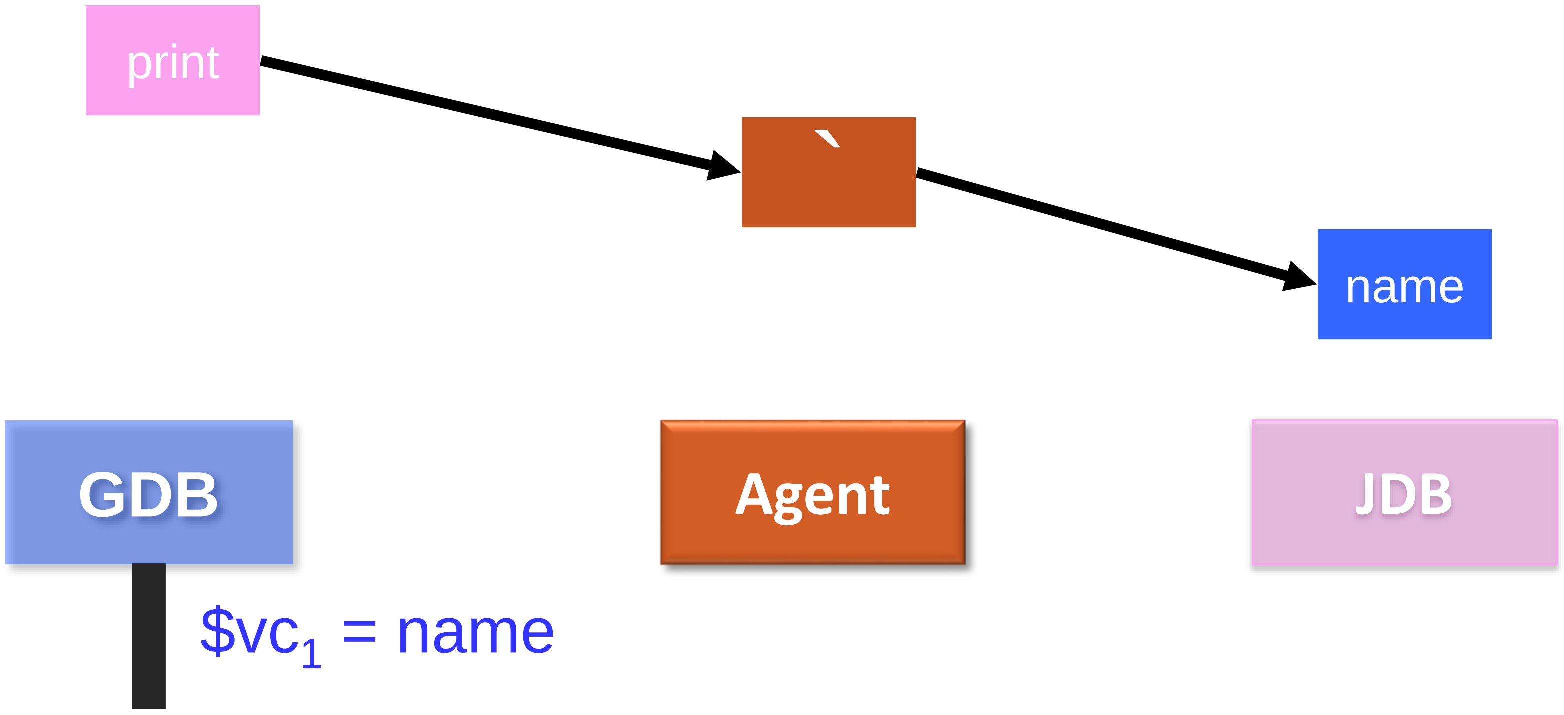


"smiley"
jstring name;
print *n e
The name is an opaque C pointer.
print `name
How can I evaluate the Jeannie expression?

Build abstract syntax tree



Evaluate AST in Bottom-up order.



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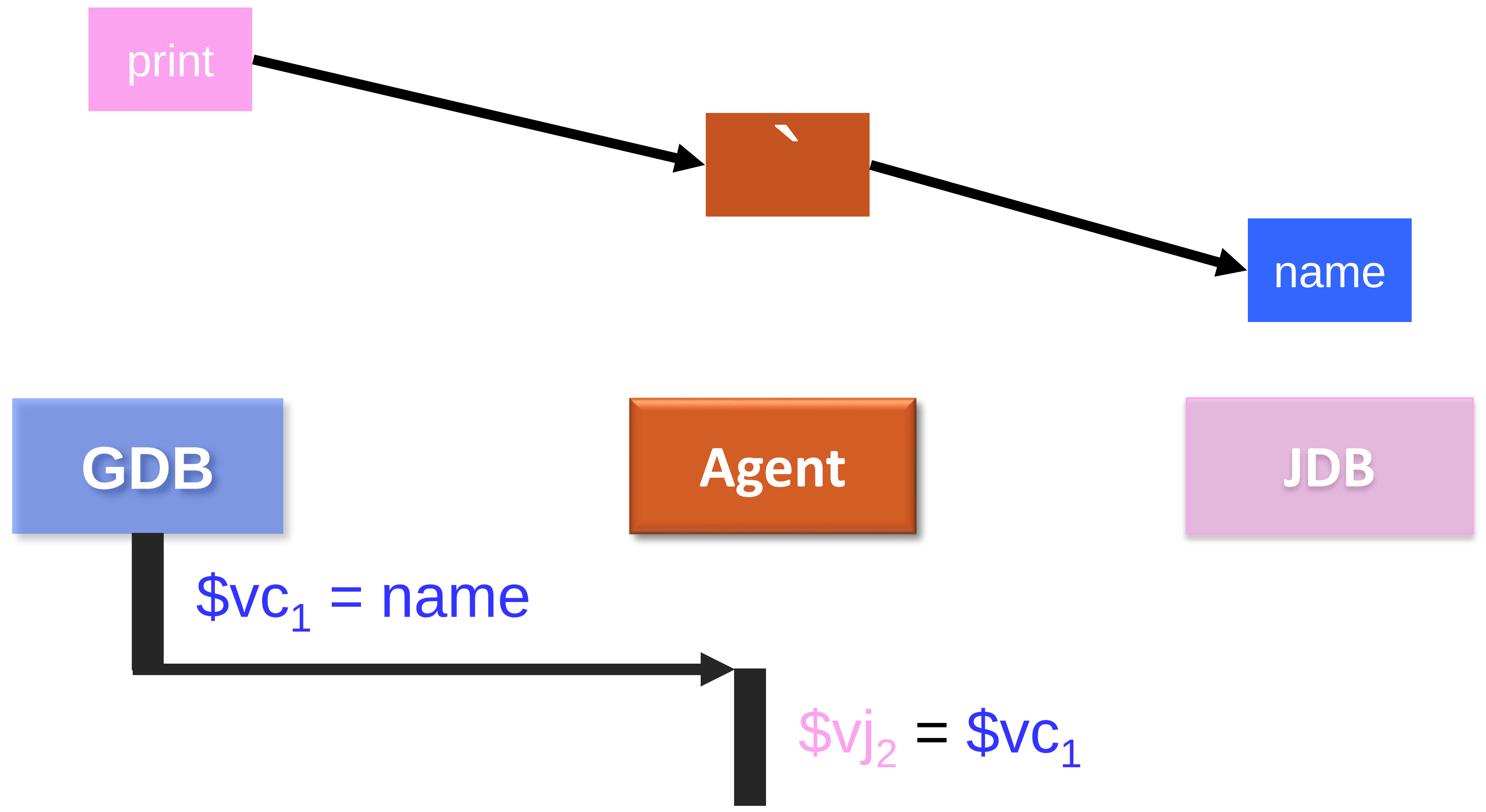

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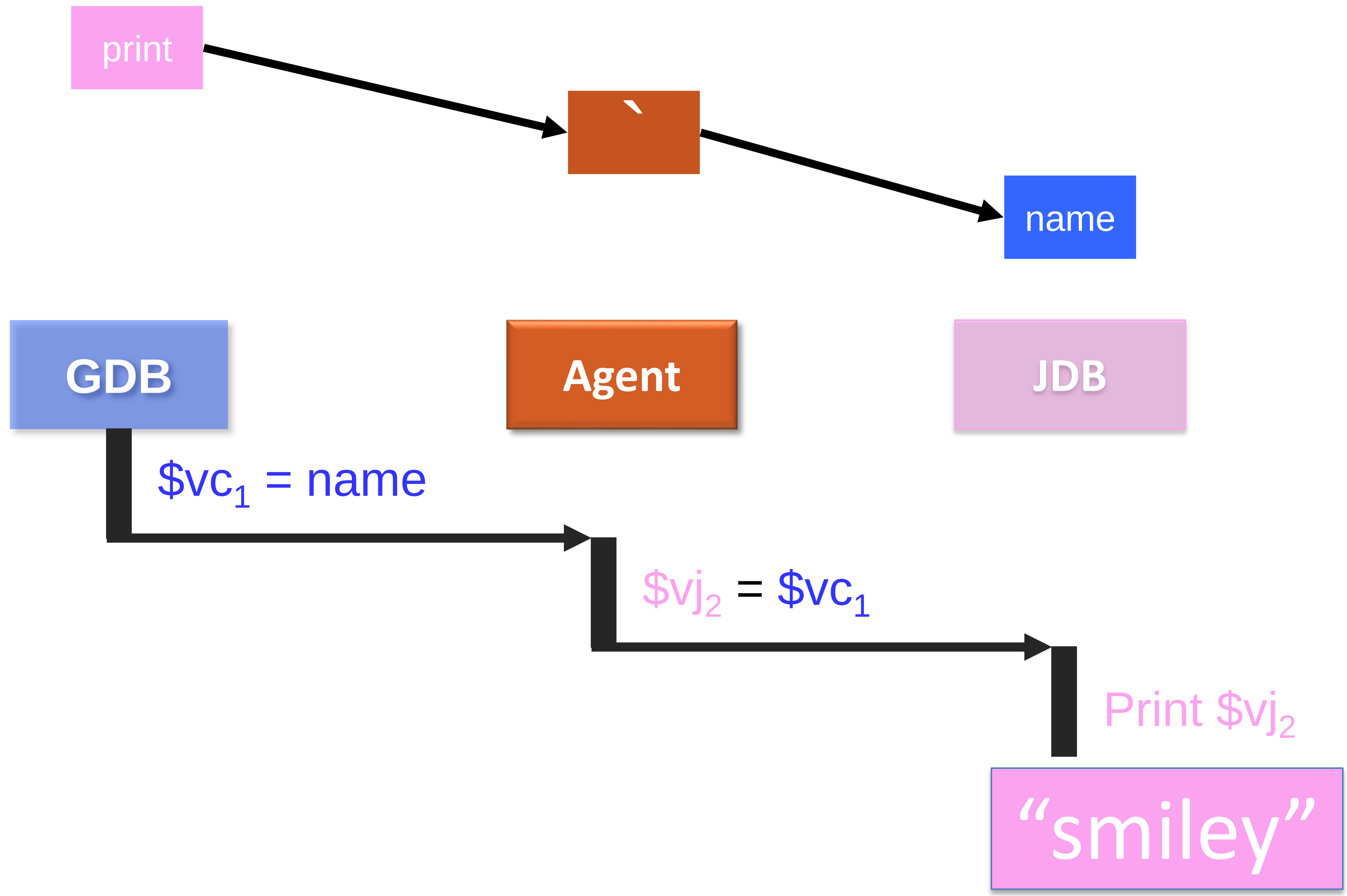
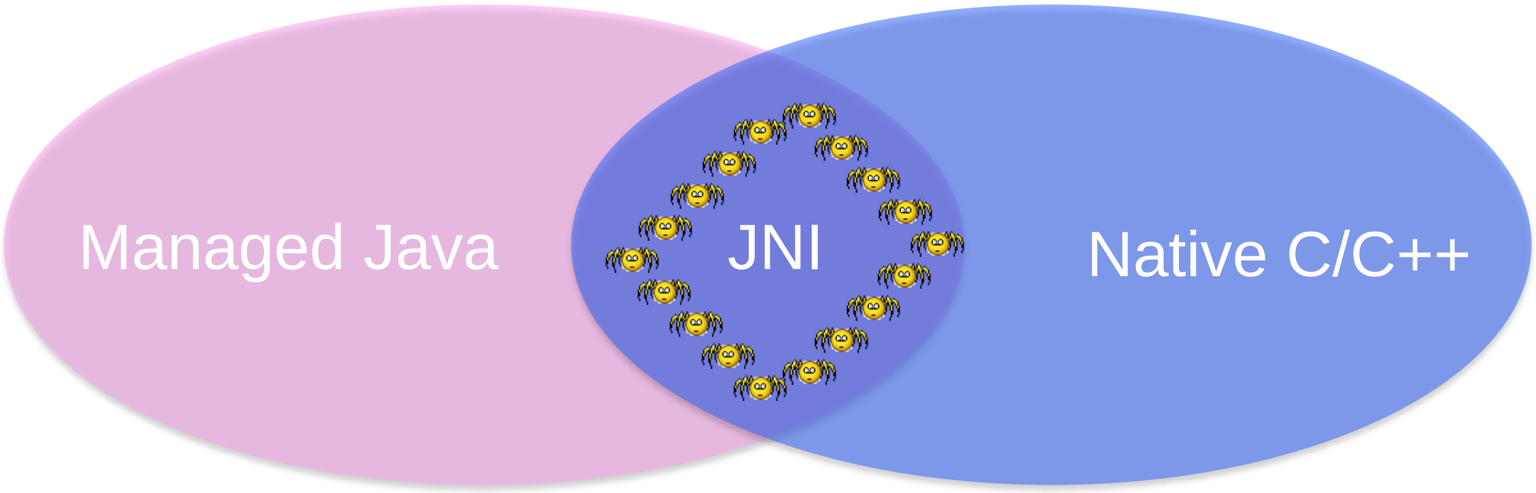
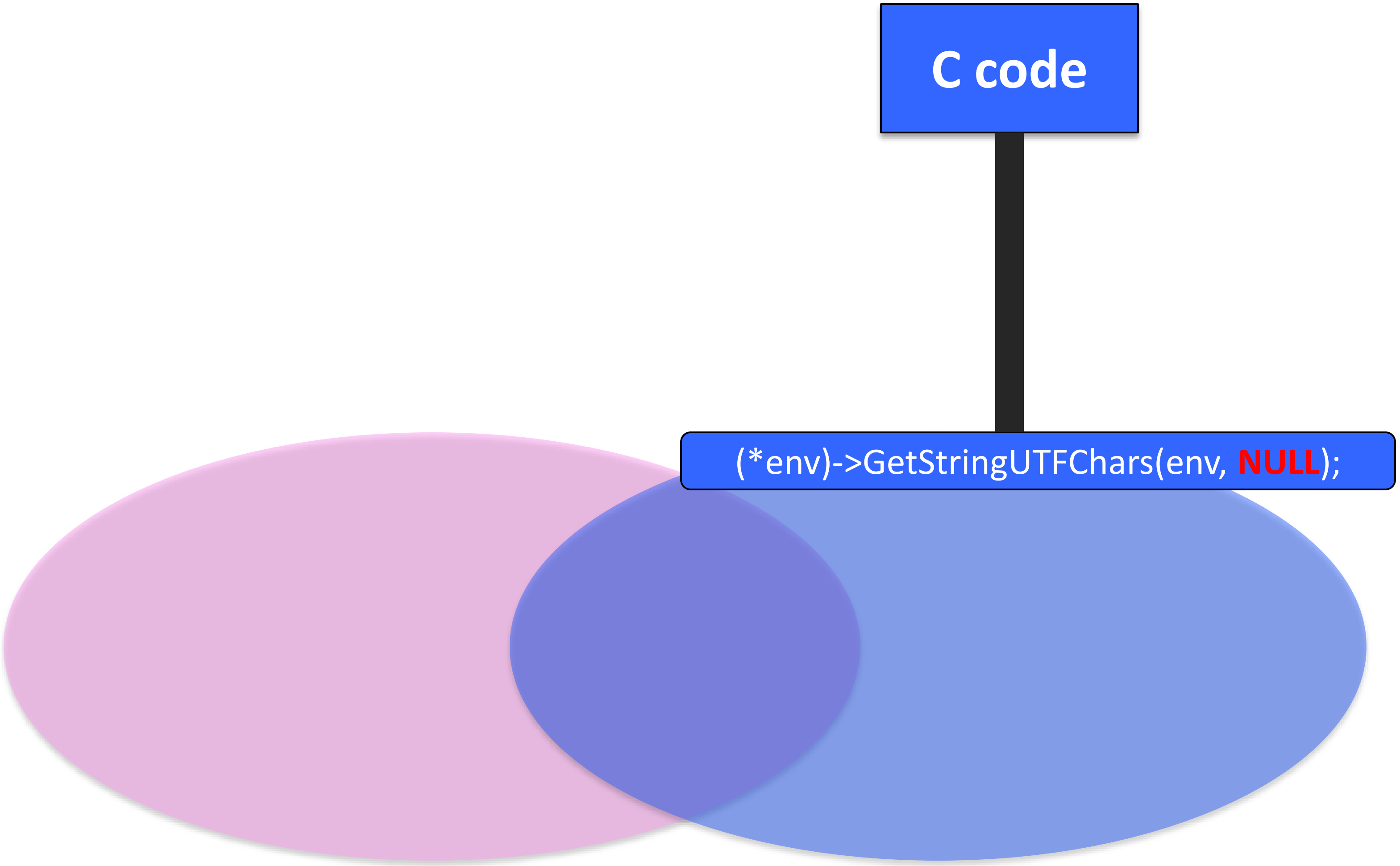


A. Evaluating Jeannie Expressions

B. Detecting FFI bugs



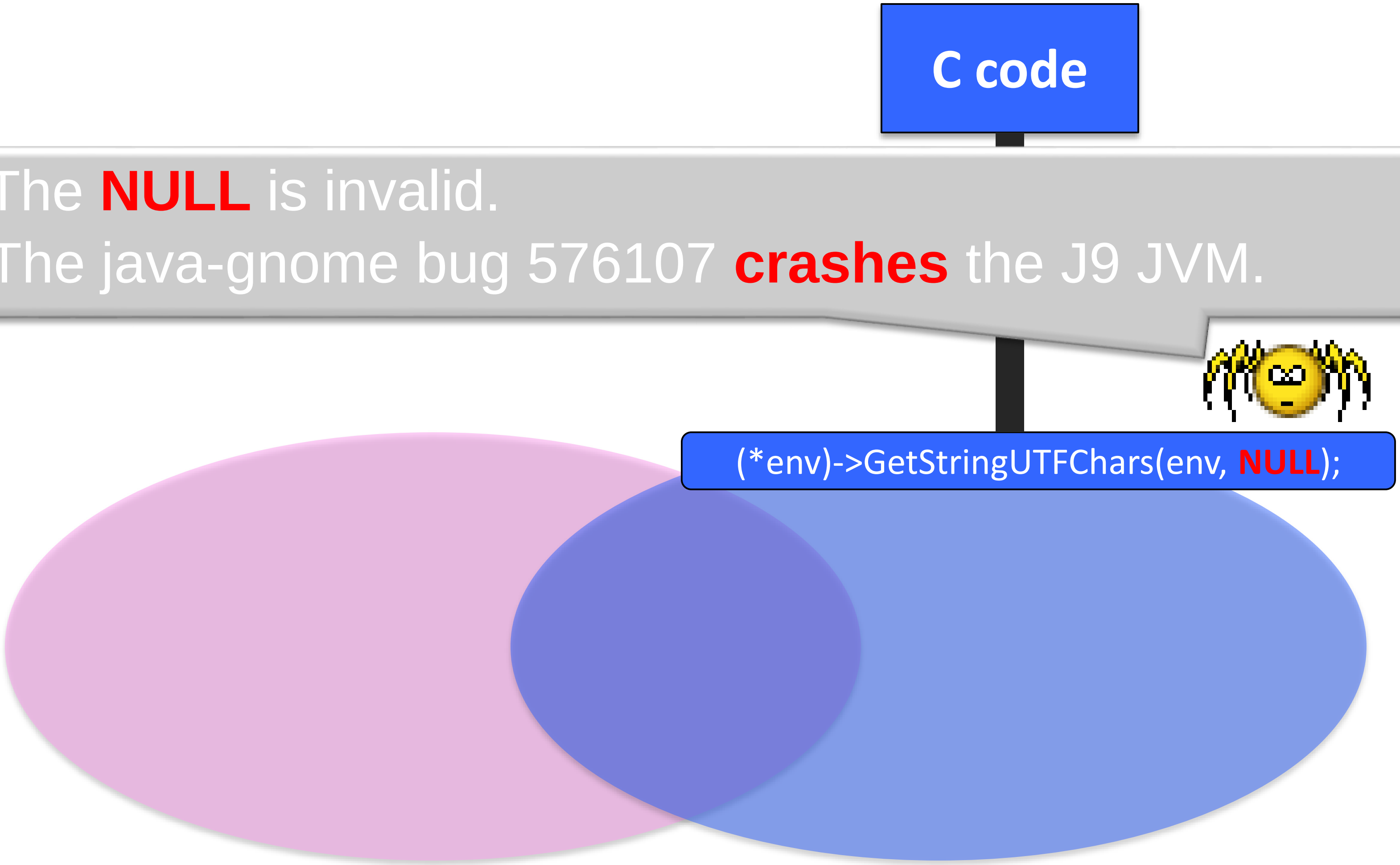
Problem: you may misuse foreign function interface.



```
(*env)->GetStringUTFChars(env, NULL);
```

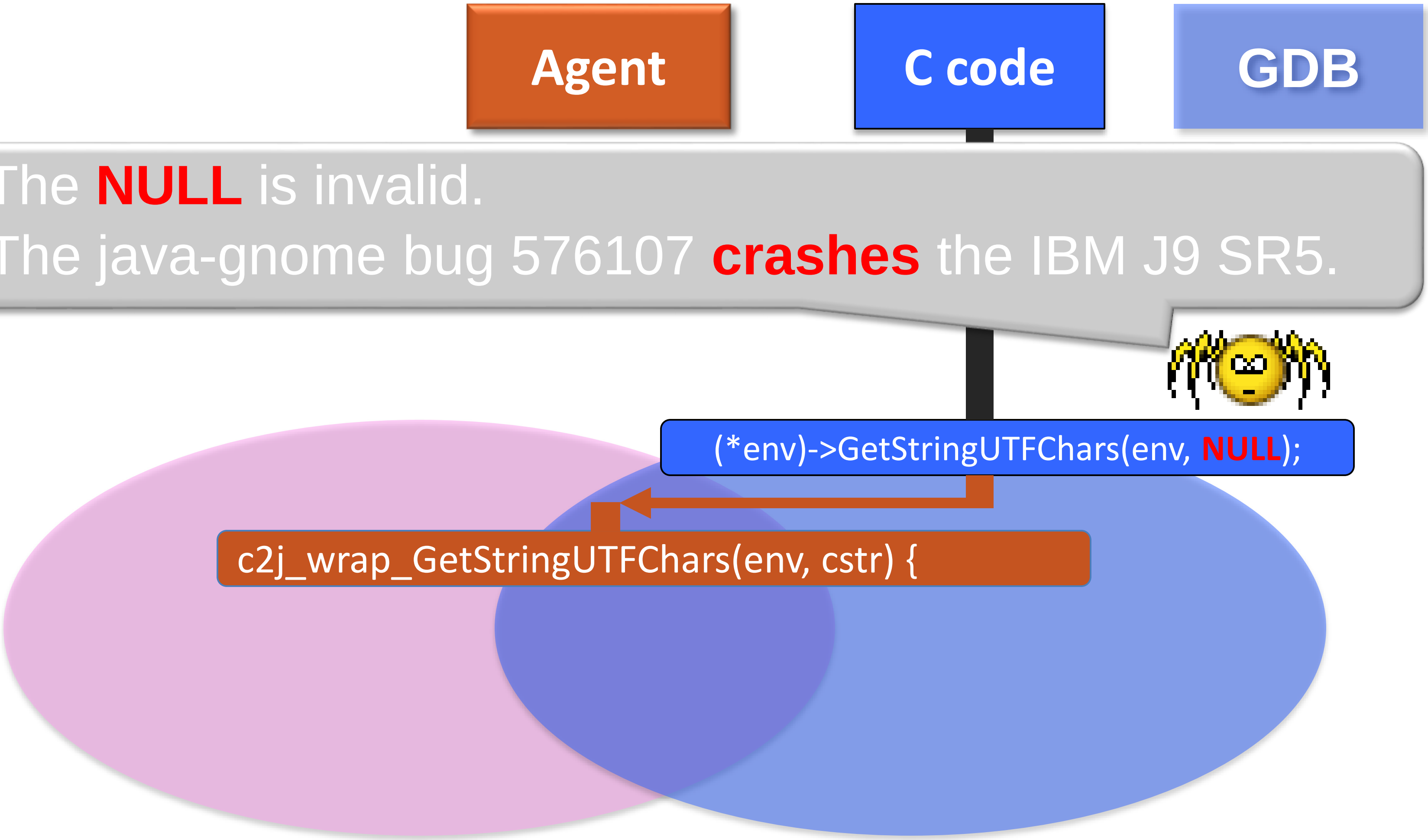
Problem: you may misuse foreign function interface.

The **NULL** is invalid.
The java-gnome bug 576107 **crashes** the J9 JVM.



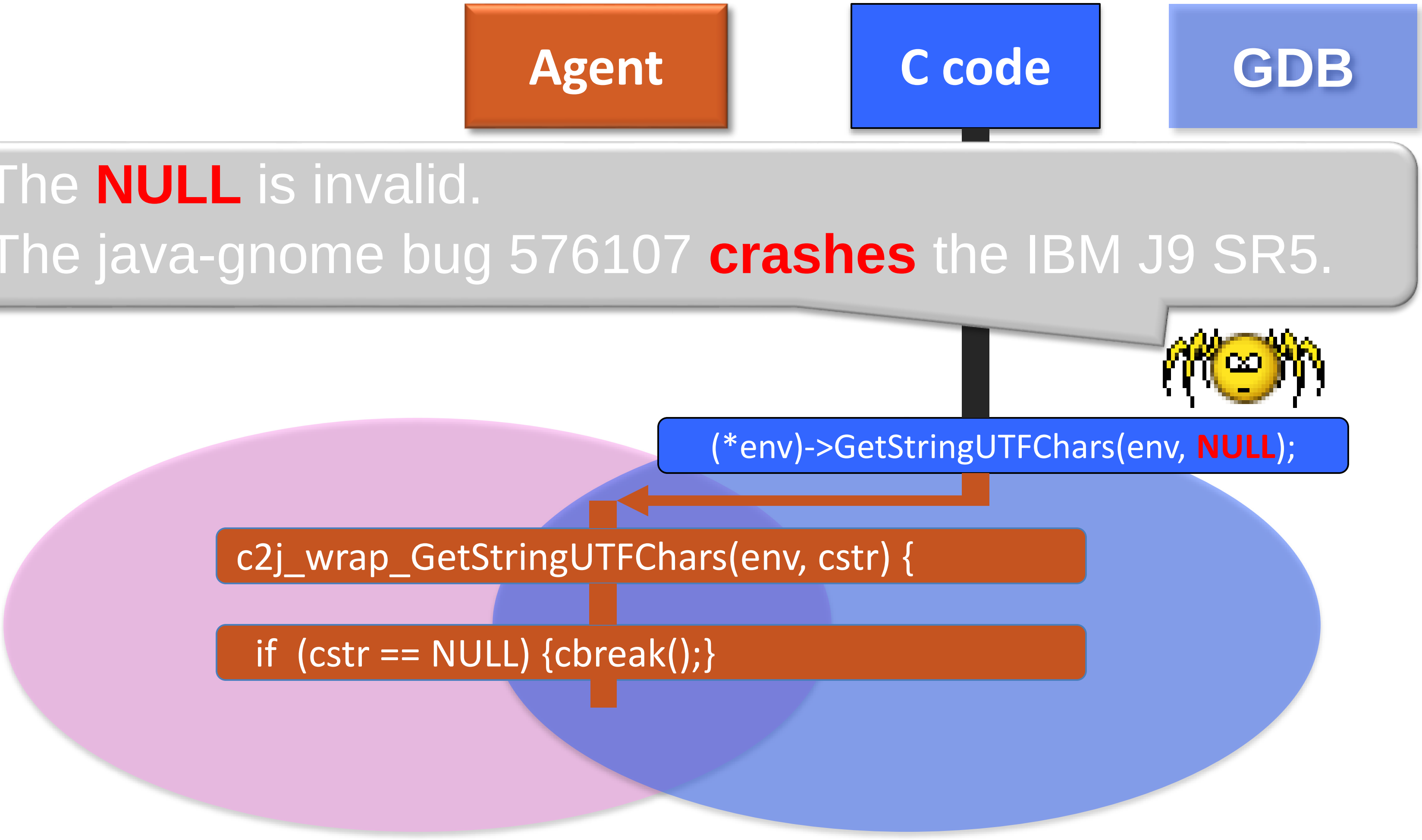
```
(*env)->GetStringUTFChars(env, NULL);
```

Our solution: detect FFI bugs


Agent
C code
GDB
(*env)->GetStringUTFChars(env, NULL);
c2j_wrap_GetStringUTFChars(env, cstr) {

The **NULL** is invalid.
The java-gnome bug 576107 **crashes** the IBM J9 SR5.

Our solution: detect FFI bugs.



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  if  (cstr == NULL) {cbreak();}
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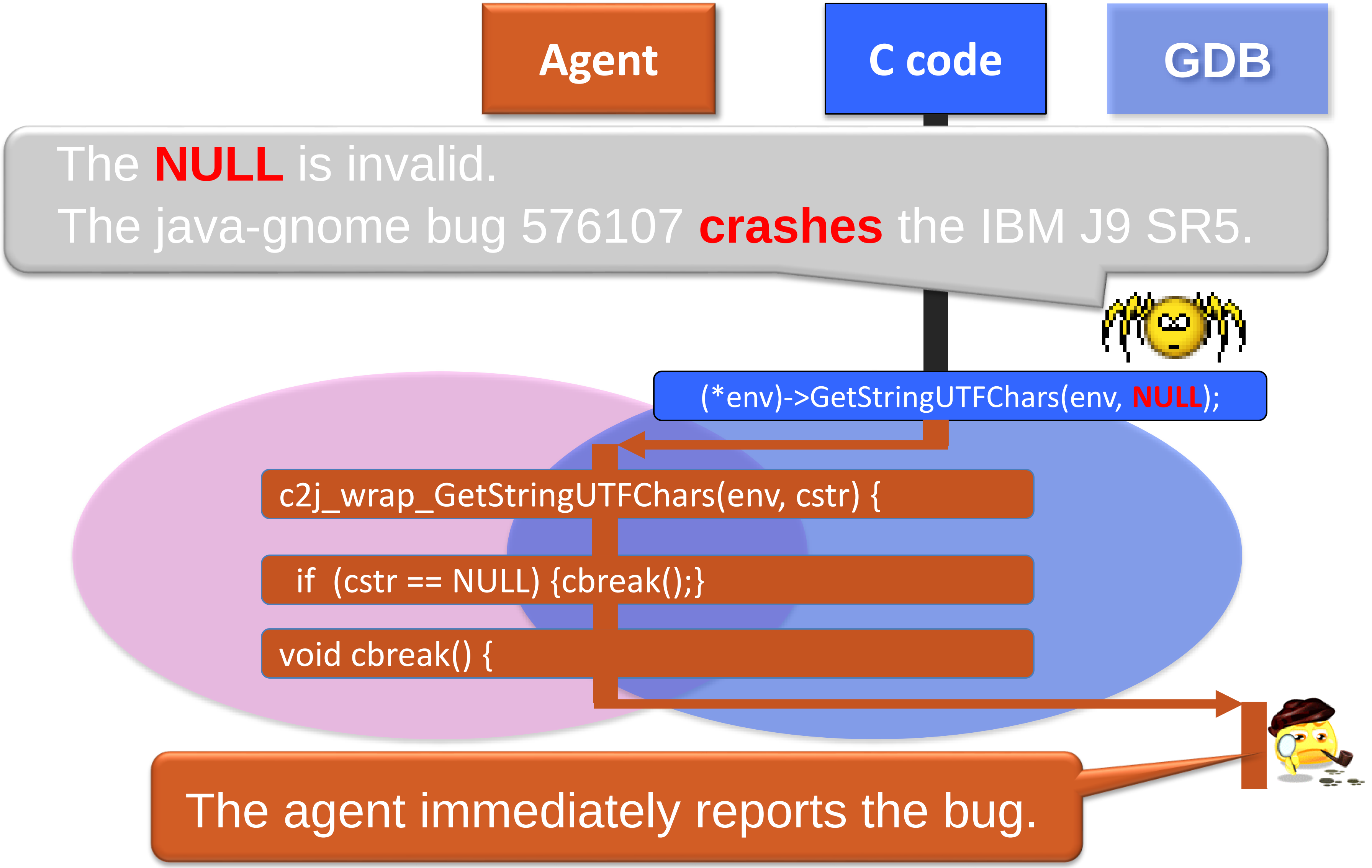

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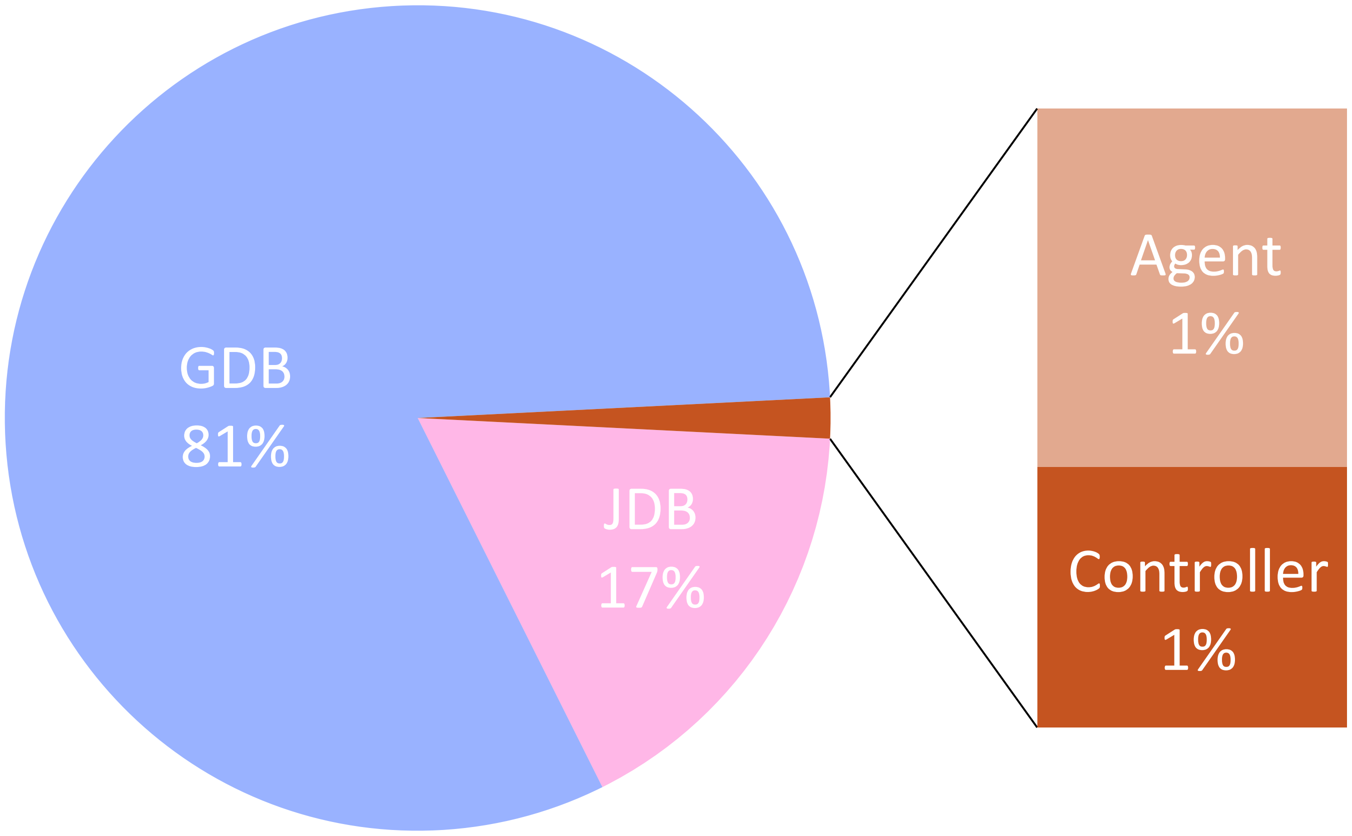
```
(*env)->GetStringUTFChars(env, NULL);
```

```
c2j_wrap_GetStringUTFChars(env, cstr) {
  if  (cstr == NULL) {cbreak();}
void cbreak() {
```

The agent immediately reports the bug.

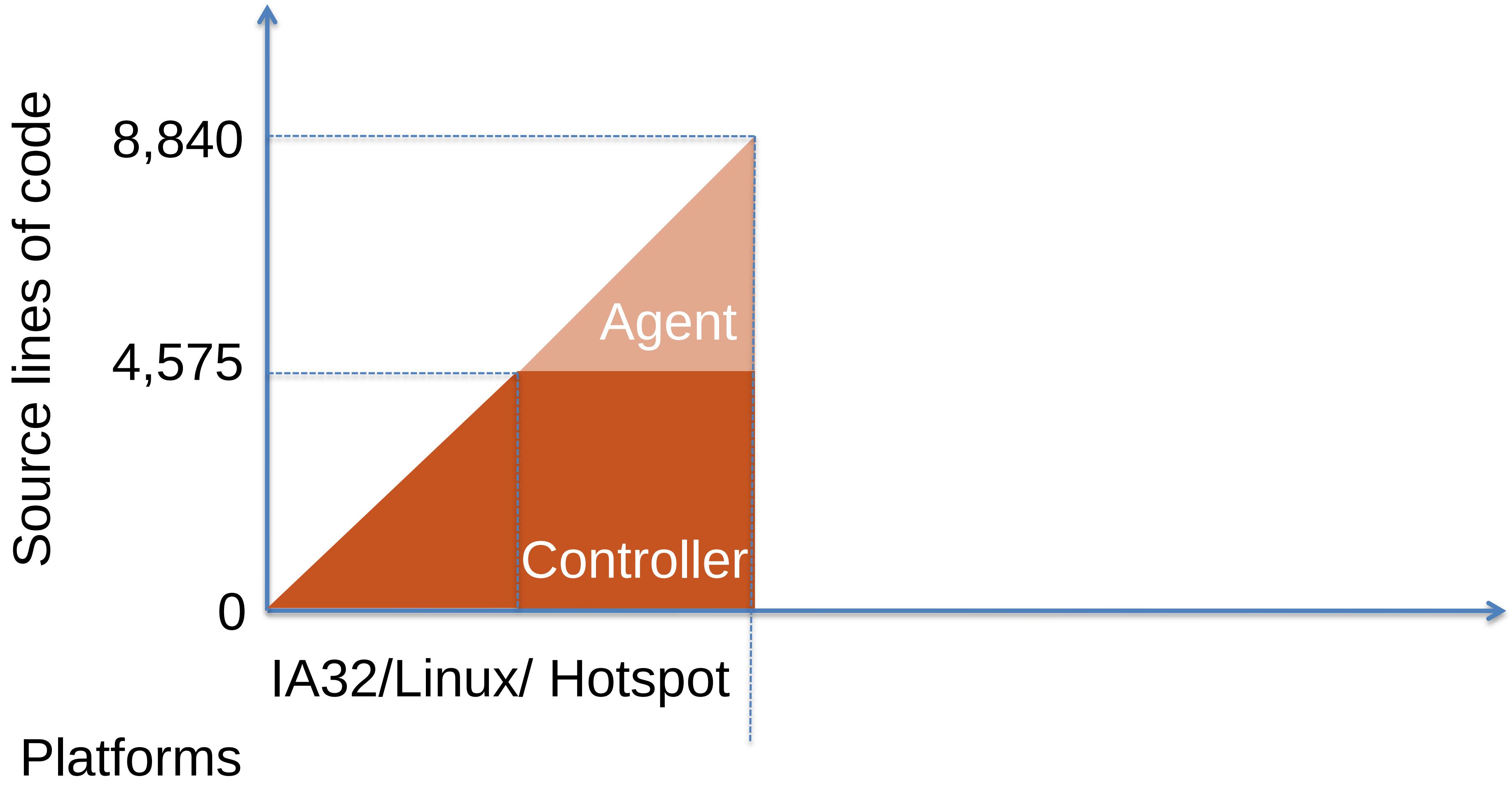
Outline

Composition is simple.



515K source lines of code in total

Composition is portable.



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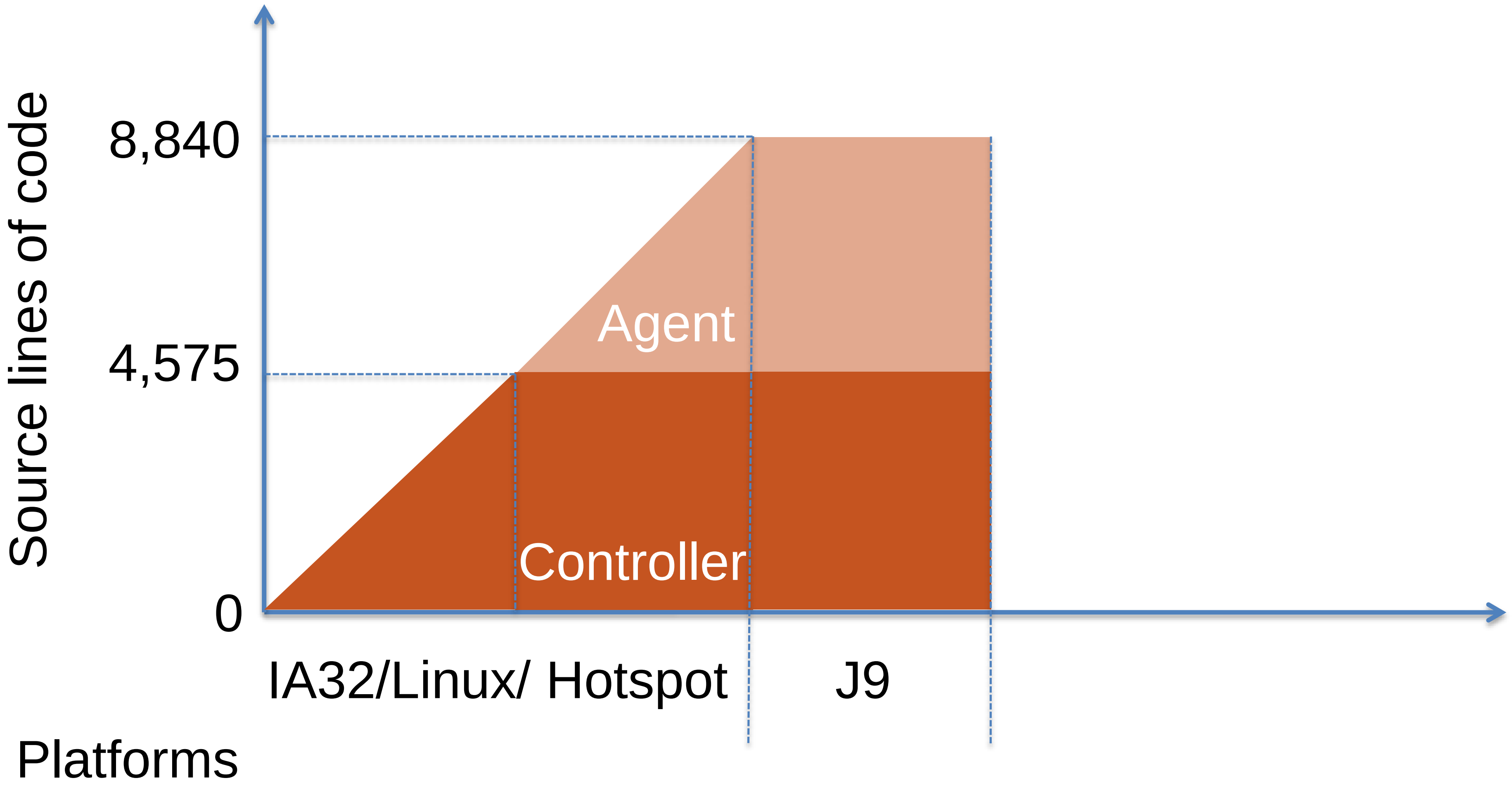

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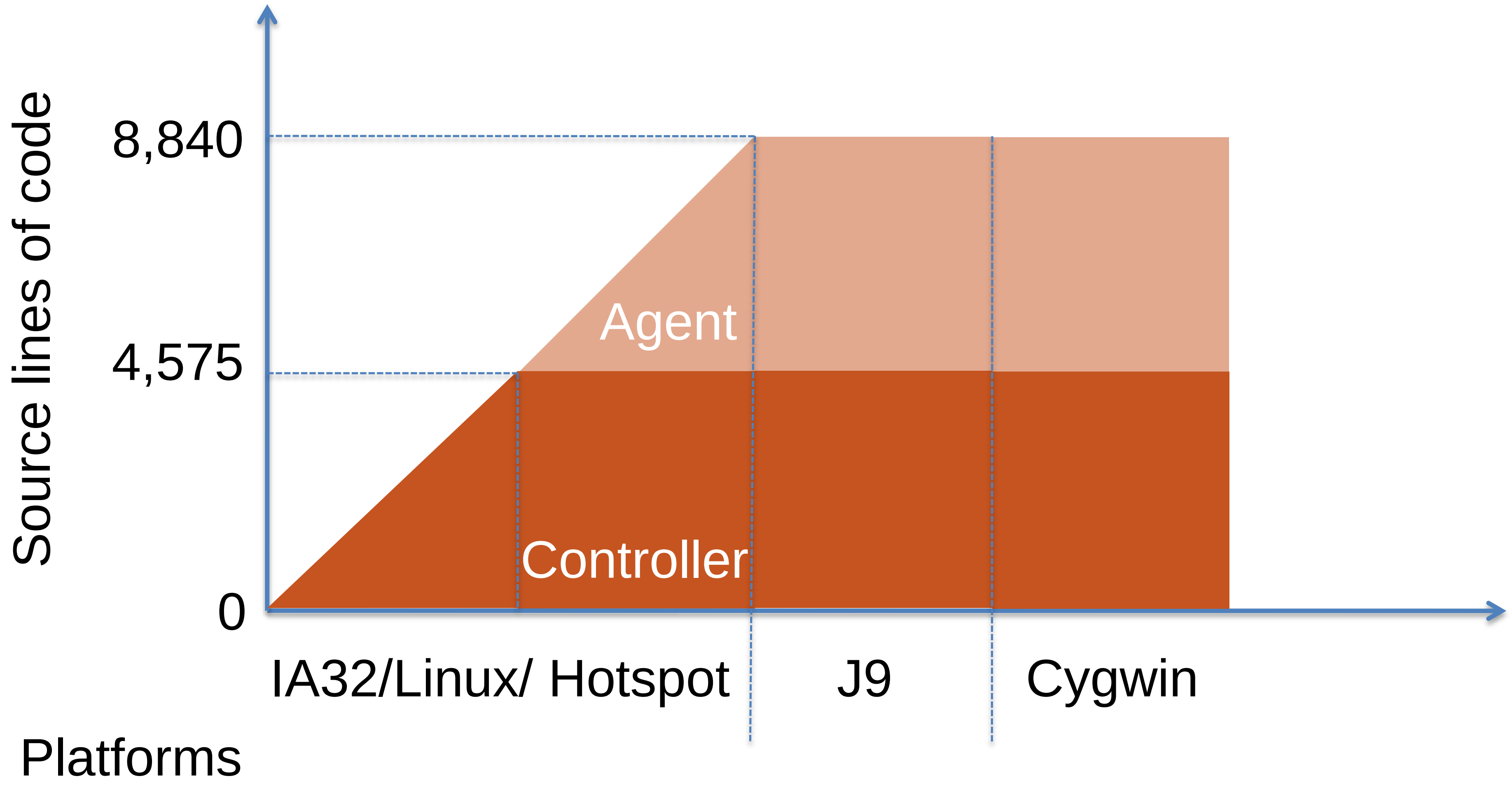

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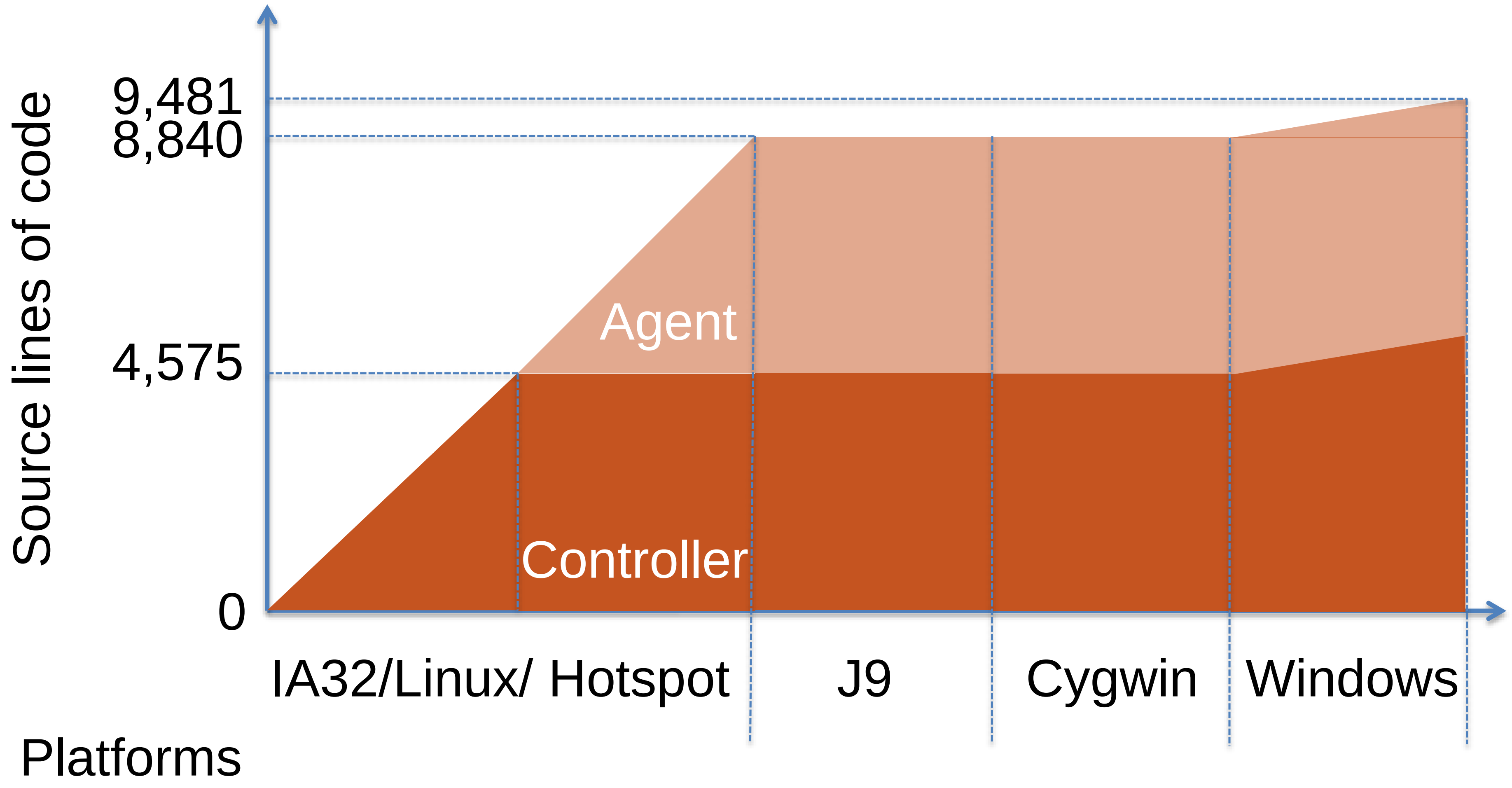

Composition is powerful.

The bug 576107 in java-gnome 4.0.10

	Hotspot VM 1.6.0_10	J9 VM SR5
Production run	running	crash

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Runtime checking (-Xcheck:jni)	warning	warning

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jdb	running	crash
gdb	running	fault

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Production run	running	crash
Runtime checking (-Xcheck:jni)	warning	warning
jdb	running	crash
gdb	running	fault
Blink	**breakpoint**	**breakpoint**

Related work

- Mixed-environment debuggers
  - Intel XDI for Harmony JVM
  - SUN dbx
  - Microsoft .NET debuggers
- Advance debugging features
  - Static analyses
    - BEAM [Kondoh & Onodera ’08]
    - J-Saffire [Furr & Foster ’06]
    - ILEA [Tan & Morrisett ‘07]
  - Language designs
    - Jeannie [Hirzel & Grimm ‘07]
    - SafeJNI [Tan et al. ‘06]
  - Wrapper generators
    - Automatic binding generator [Ravitch ‘09]
    - SWIG [Beazley ‘96]

Summary

- Portable mixed-environment debugging
- Composition with an intermediate agent
  1. Switching debugger context
  2. Interposing transitions
- Results
  1. Simple
  2. Portable
  3. Powerful

Thank you