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Introduction to **DiSL**

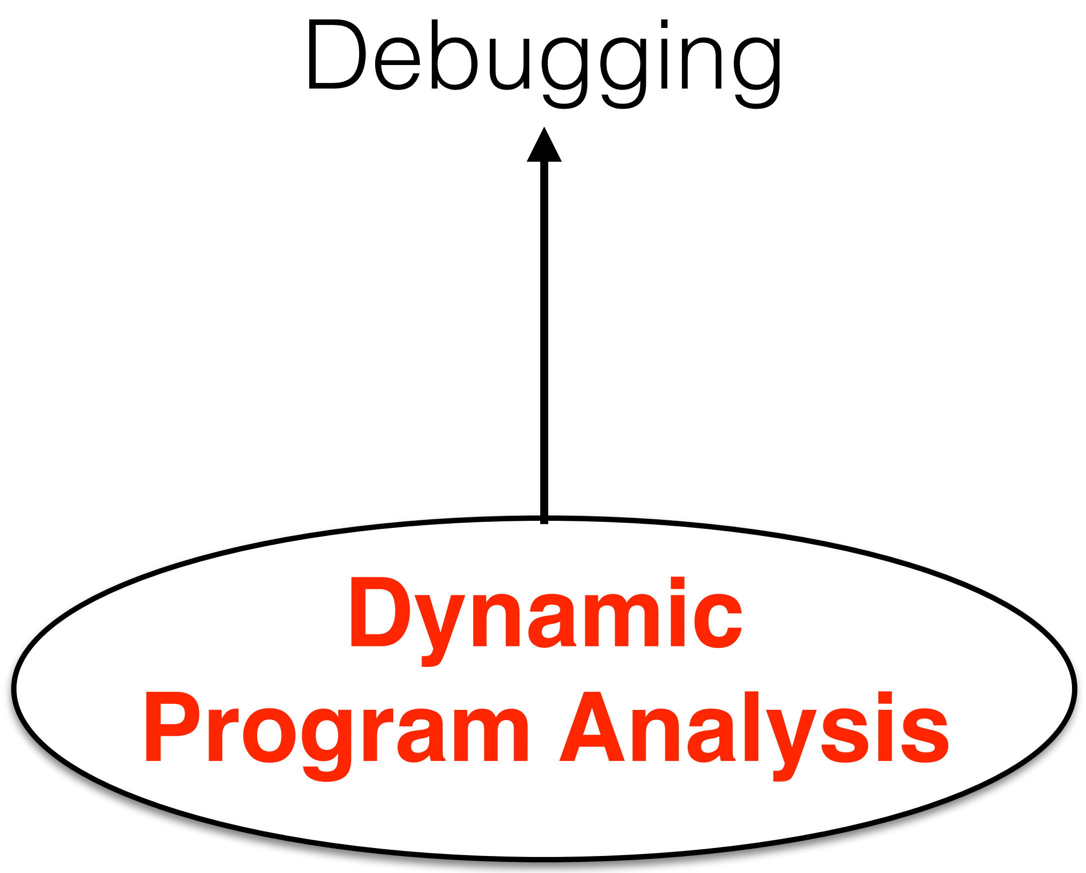
Yudi Zheng

Domain **S**pecific **L**anguage for bytecode **i**nstrumentation

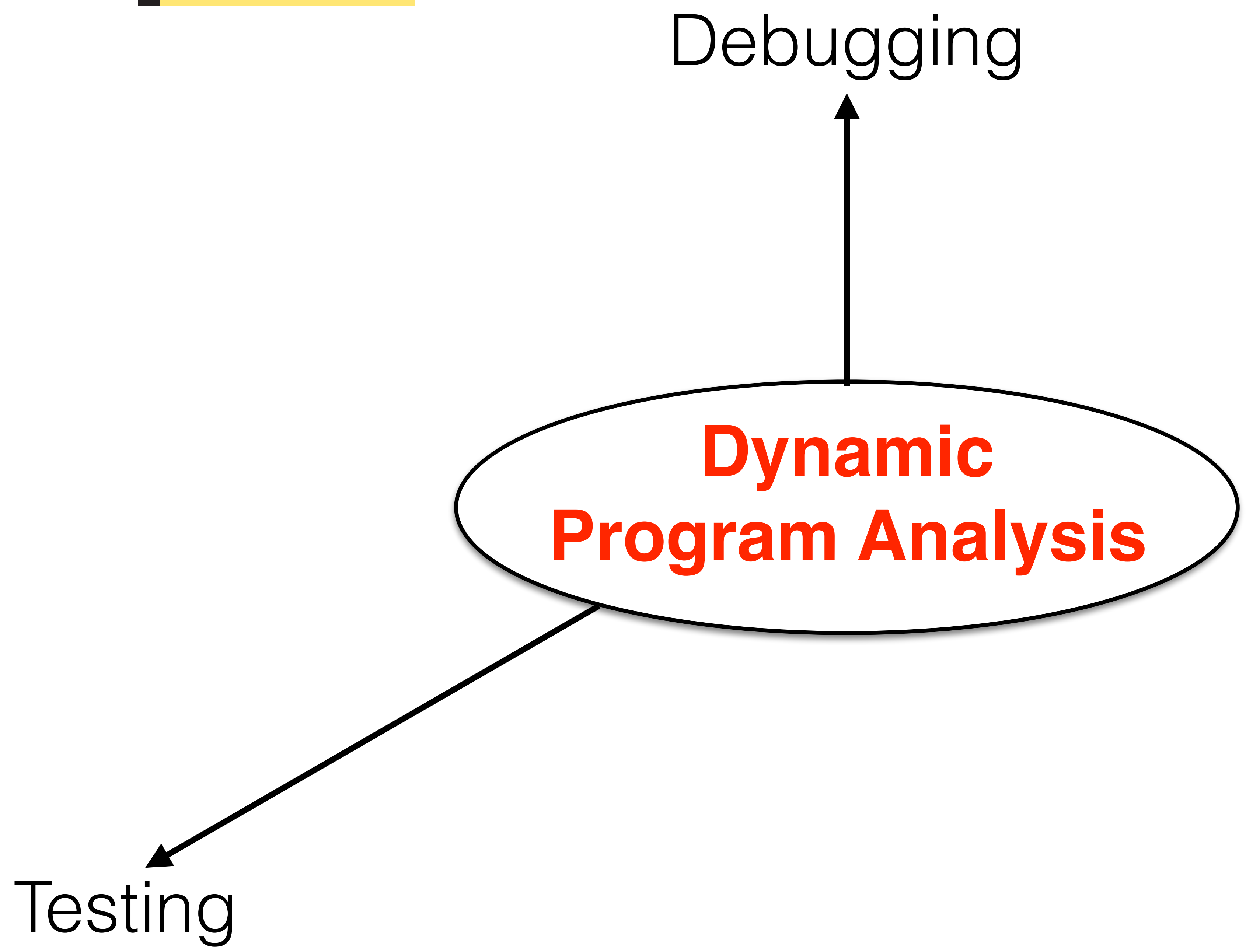
DiSL targets ...

**Dynamic
Program Analysis**

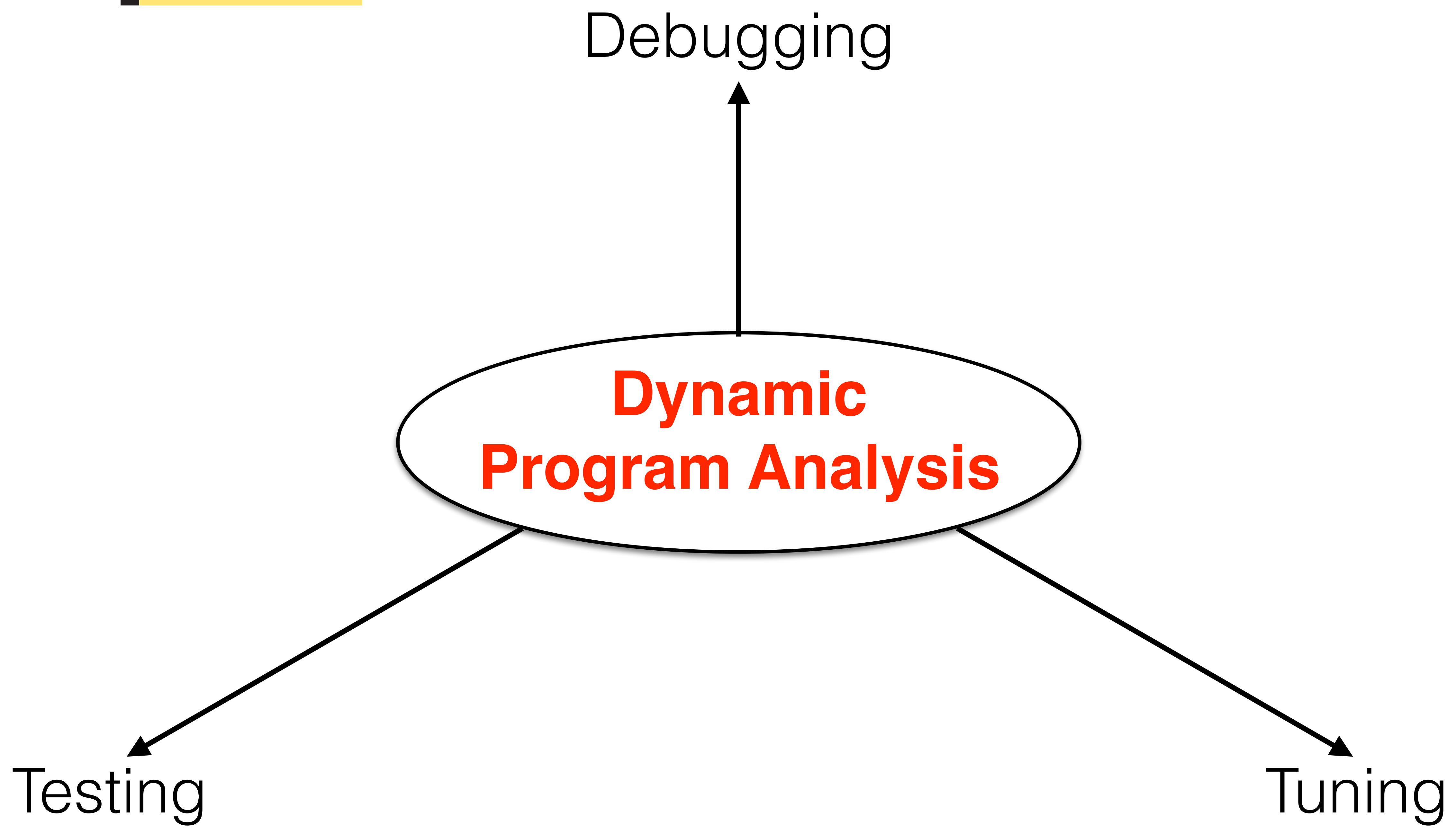
DiSL targets ...



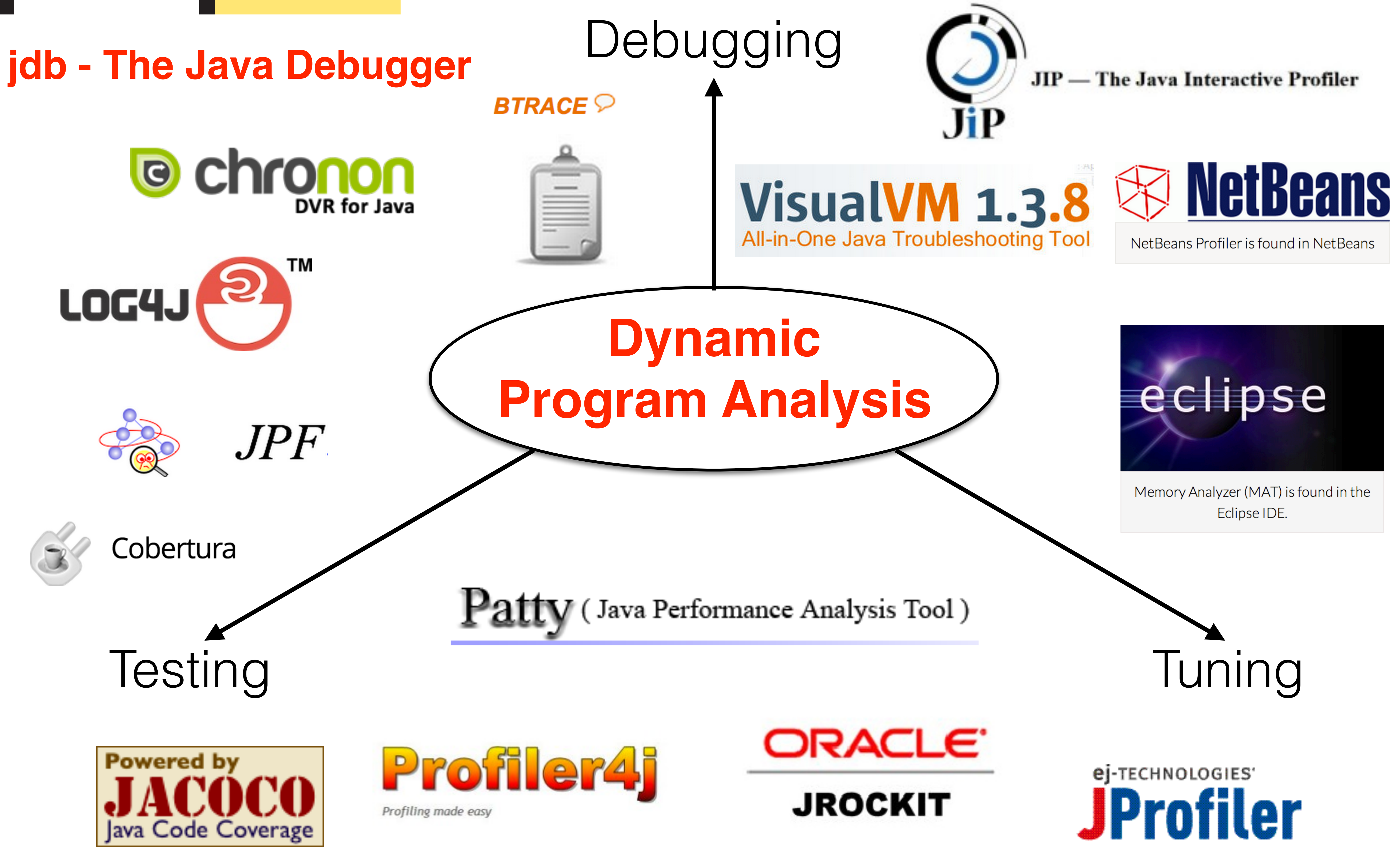
DiSL targets ...



DiSL targets ...



DiSL targets ...


jdb - The Java Debugger
BTRACE
Debugging
JIP — The Java Interactive Profiler
JiP
chronon DVR for Java
VisualVM 1.3.8
All-in-One Java Troubleshooting Tool
NetBeans
NetBeans Profiler is found in NetBeans
LOG4J
Dynamic Program Analysis
eclipse
Memory Analyzer (MAT) is found in the Eclipse IDE.
JPF
Cobertura
Patty (Java Performance Analysis Tool)
Testing
Tuning
Powered by JACOCO Java Code Coverage
Profiler4j Profiling made easy
ORACLE JROCKIT
ej-TECHNOLOGIES JProfiler

TALK IS CHEAP.
SHOW ME THE CODE.

DiSL code

DiSL code

```
@Before(marker = BodyMarker.class,
        scope = "Helloworld.main")
static void premain() {
  System.out.println("Hello, DiSL");
}
```

DiSL code

Annotation: describes ***where*** *to instrument*

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*Method Body: describes **what** to instrument*

DiSL code

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>_
Demo

How **DiSL** instruments

How **DiSL** instruments

```
                Helloworld.java

public class Helloworld {
  public static void main(String[] args) {
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  }
}
```

← Target Class

How DiSL instruments

DiSL
Class →

HelloDiSL.java

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Helloworld.java

```
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← Target
Class

How DiSL instruments

1. Identify the instrumentation locations →

HelloDiSL.java

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Helloworld.java

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public class Helloworld {
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How DiSL instruments

2. Extract the method body →

```
System.out.println("Hello, DiSL");
```

```
            Helloworld.java

public class Helloworld {
  public static void main(String[] args) {
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How **DiSL** instruments

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← **3. Instrument**

Approach

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Approach

```
> java -cp bin-target demo1.Helloworld
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Approach

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Approach

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Hellow
CLASS
Java Virtual Machine

Approach

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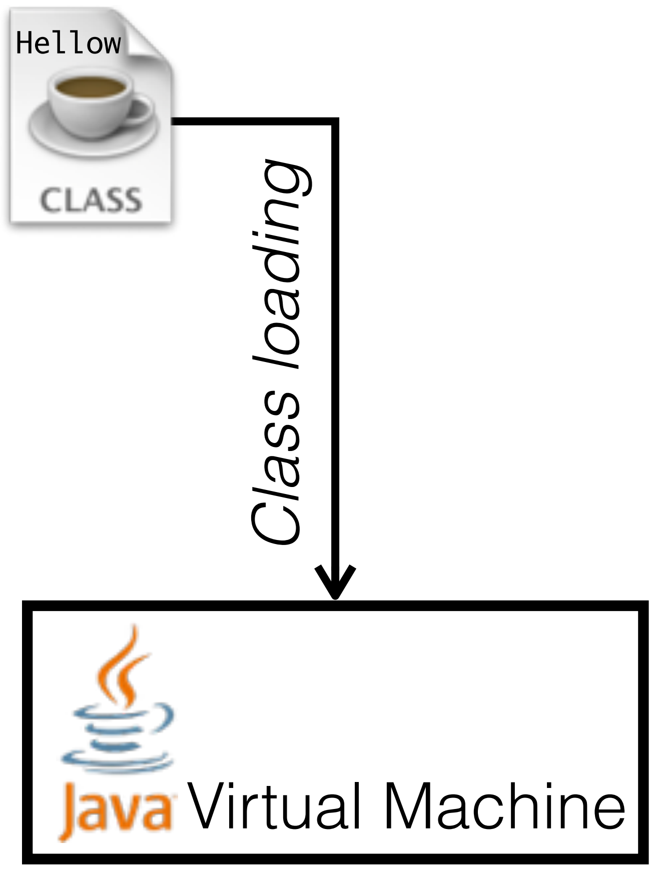

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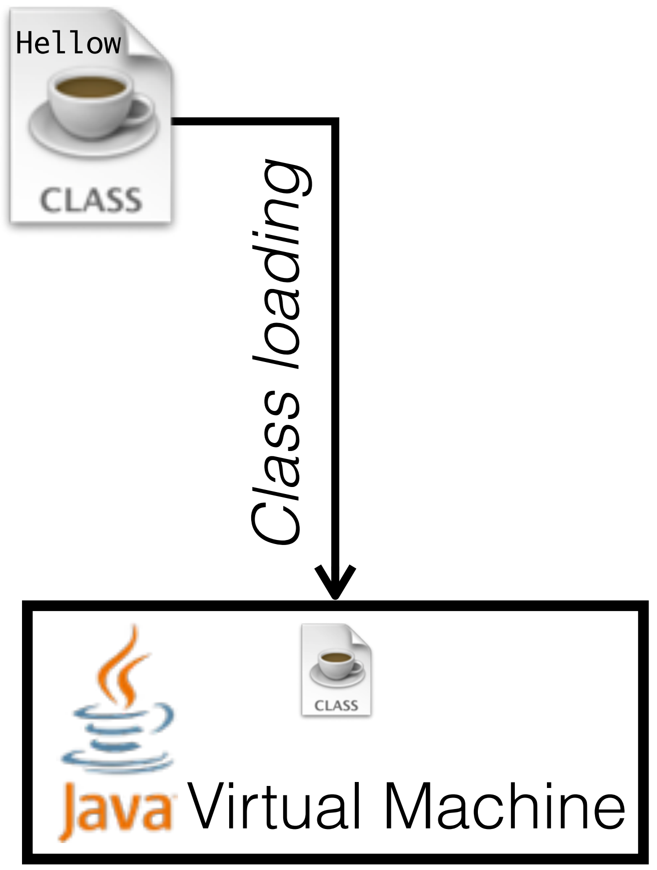

Approach

```
> java -agentpath:lib/libdislagent.jnilib
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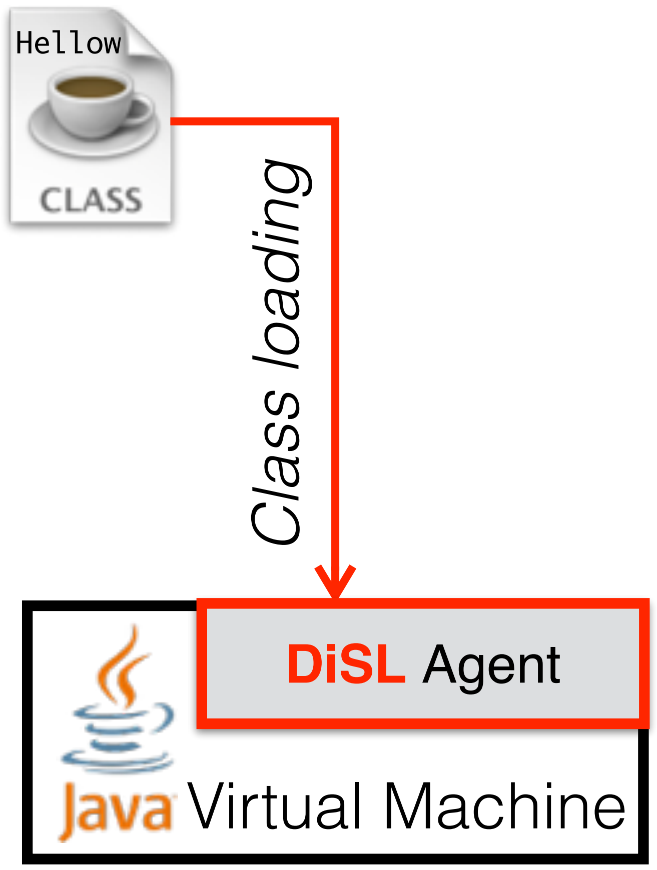
       -cp bin-target demo1.Helloworld
```



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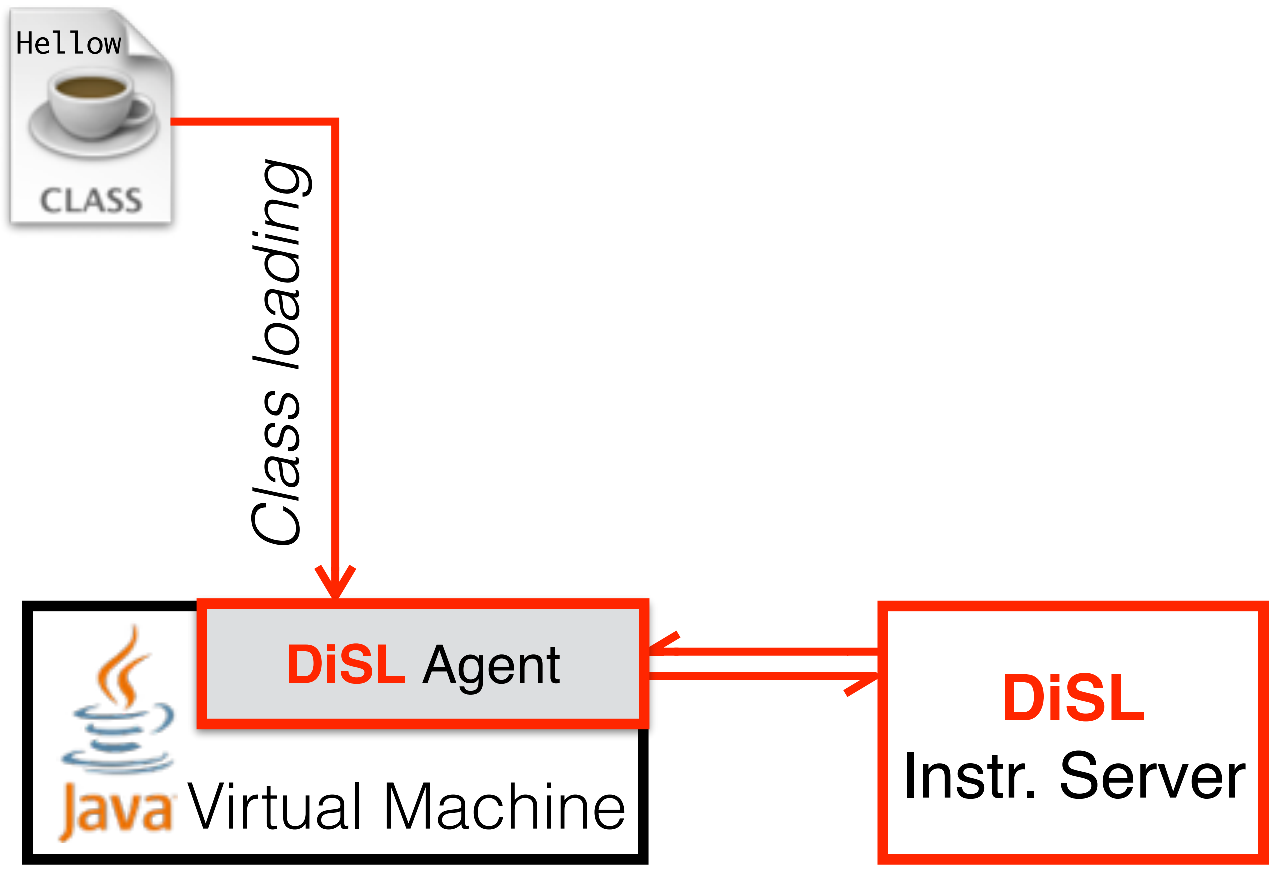

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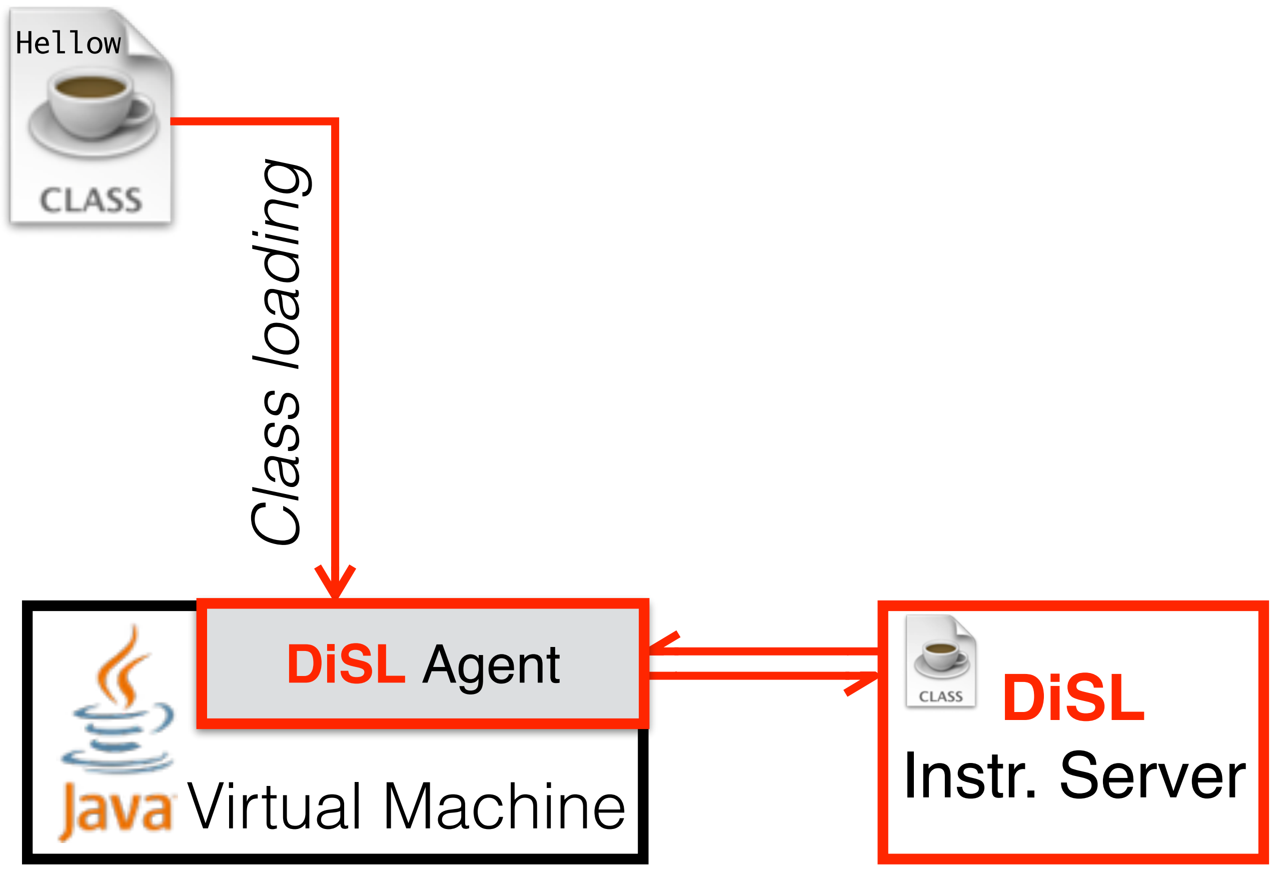

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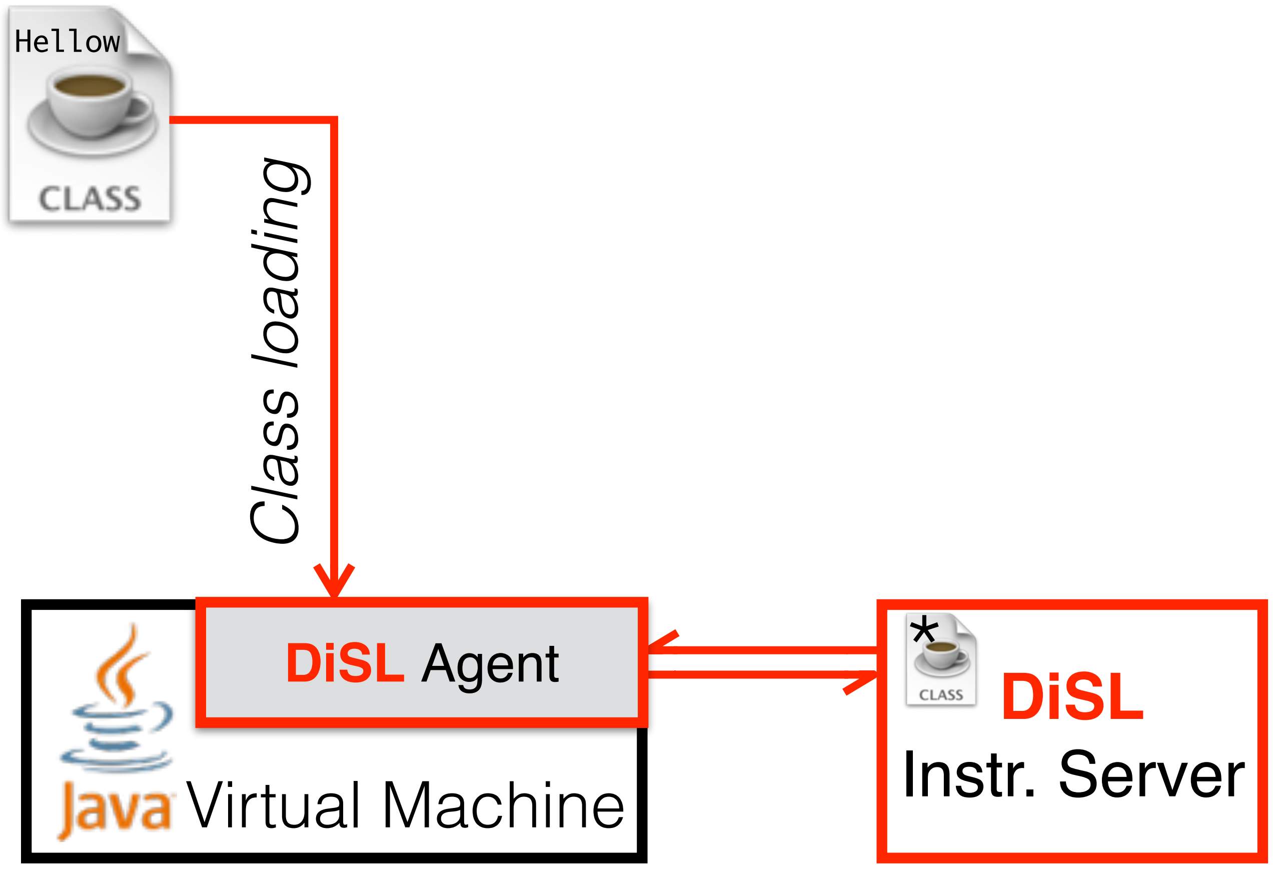

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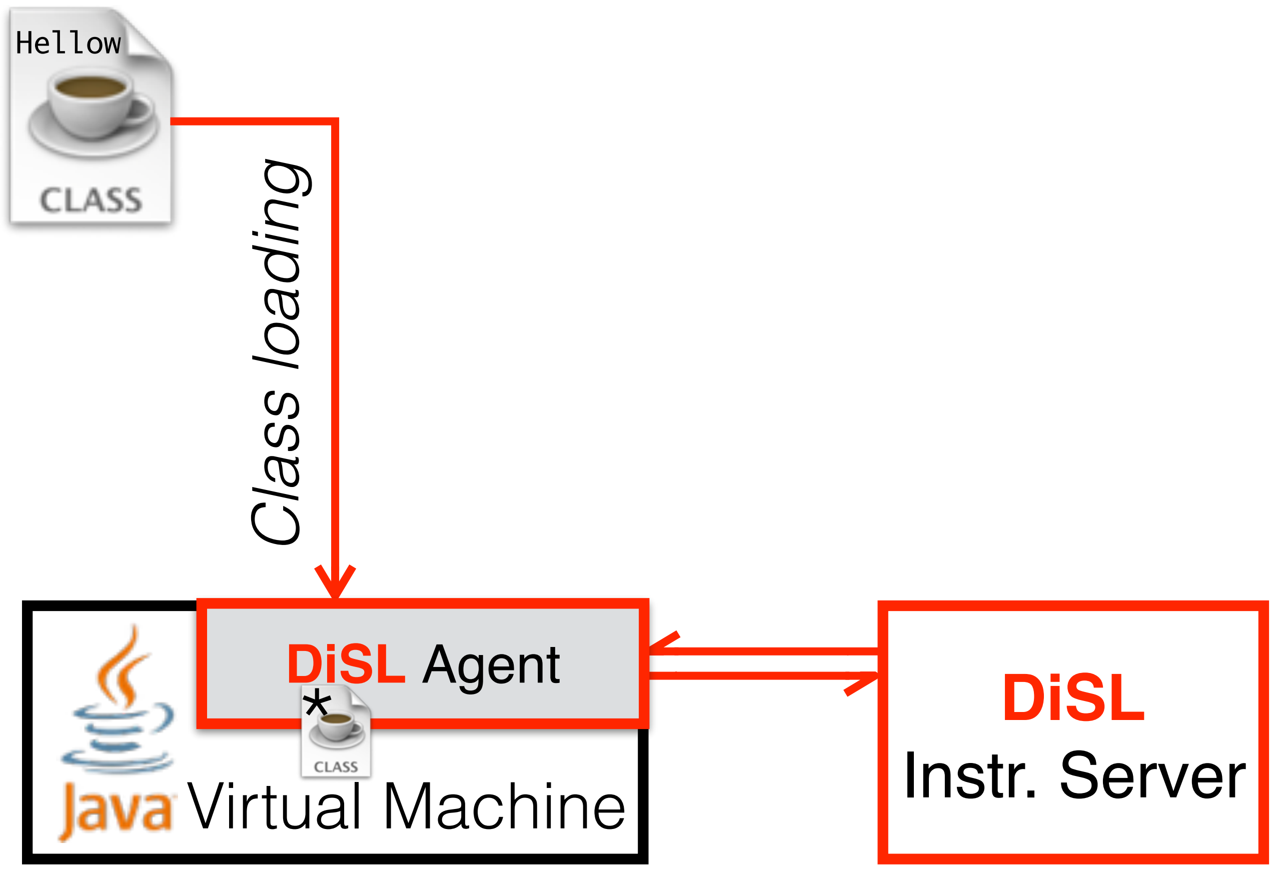

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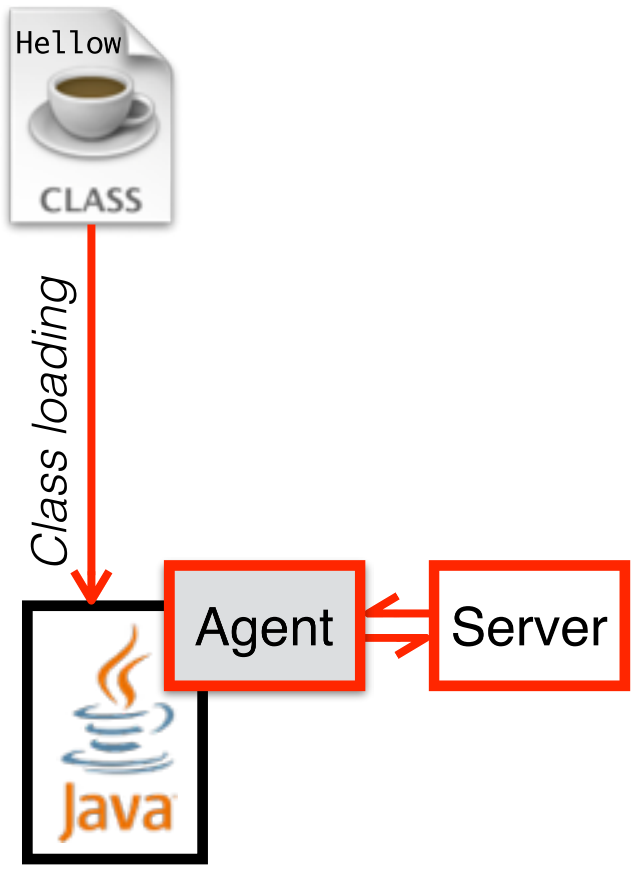

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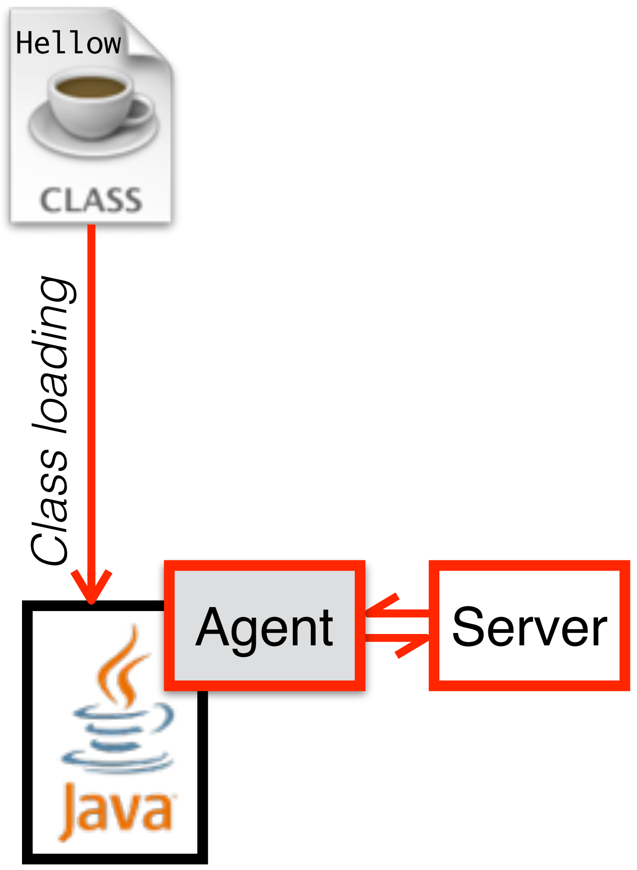

V.S.

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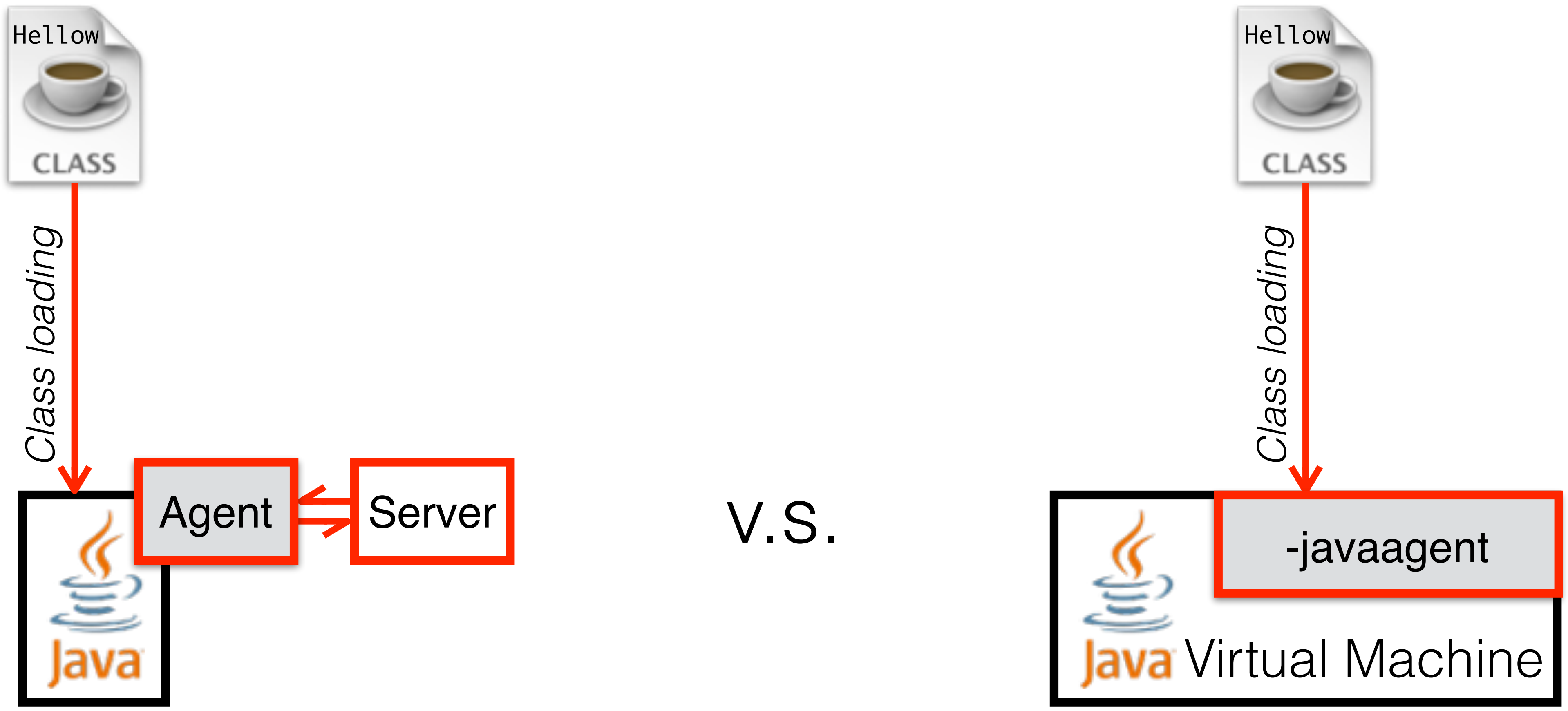

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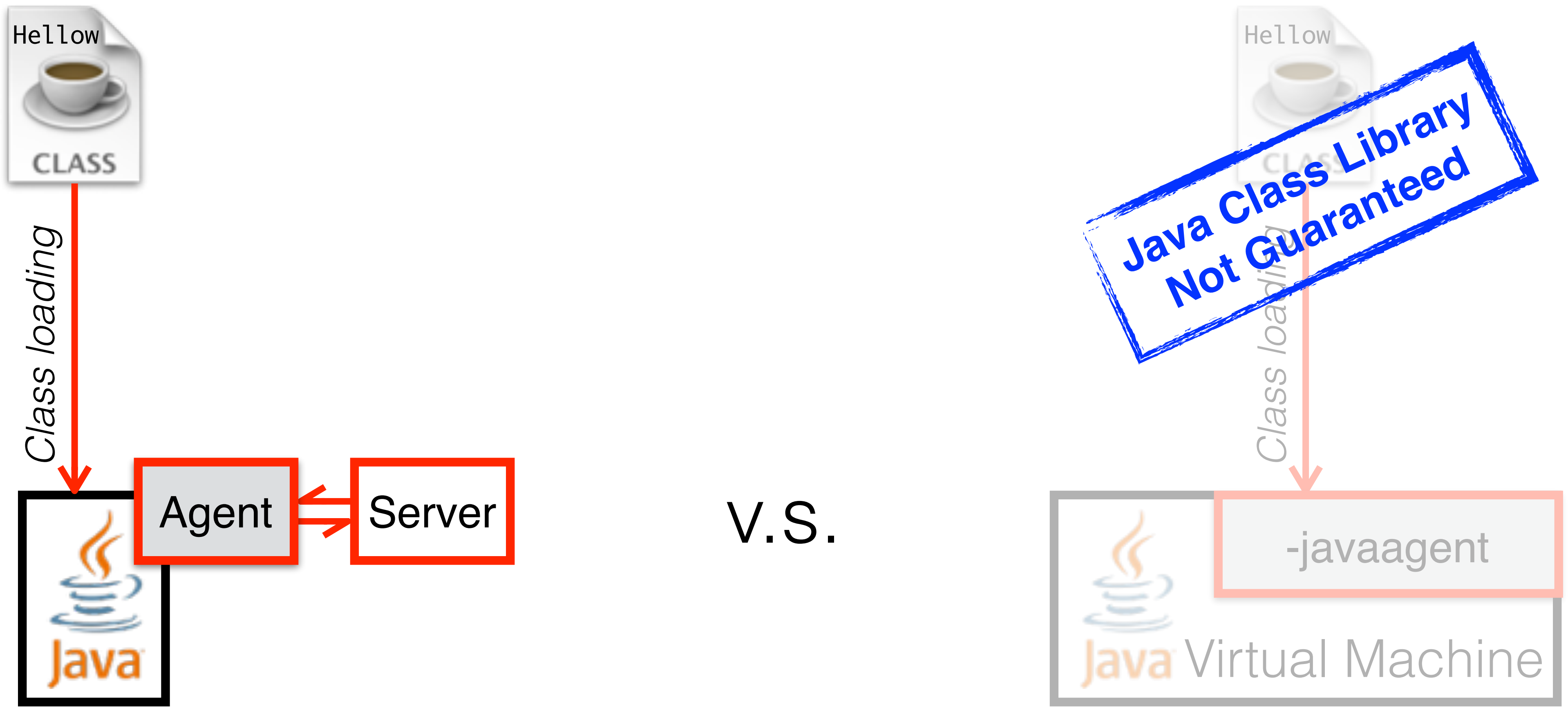

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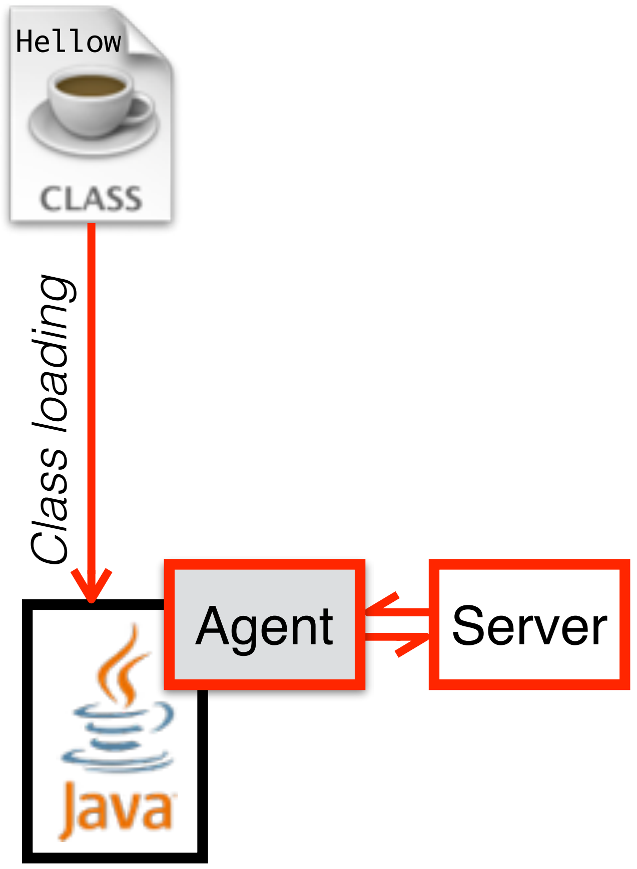
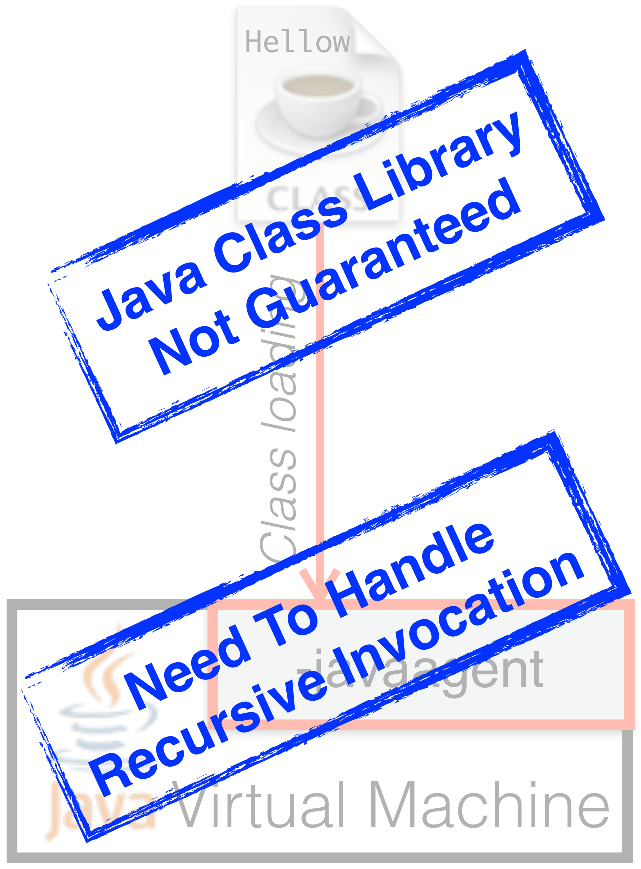


V.S.


Hellow
CLASS
Class loading
javaagent
Java Virtual Machine
Java Class Library Not Guaranteed
Need To Handle Recursive Invocation

Recursive Invocation

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@Before(marker = BodyMarker.class,
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>_
Demo

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Example: mvn

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Example: mvn

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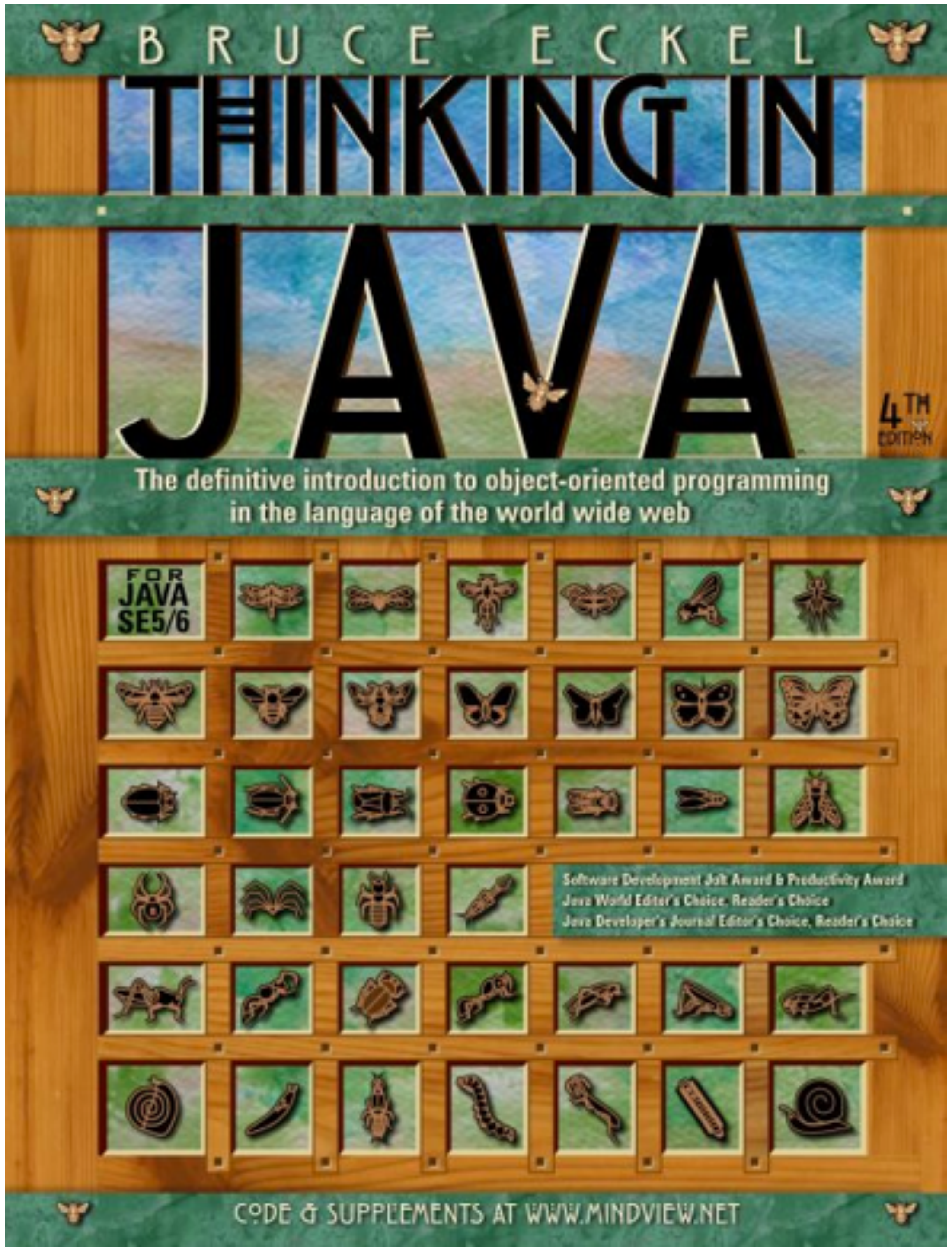
>_ Demo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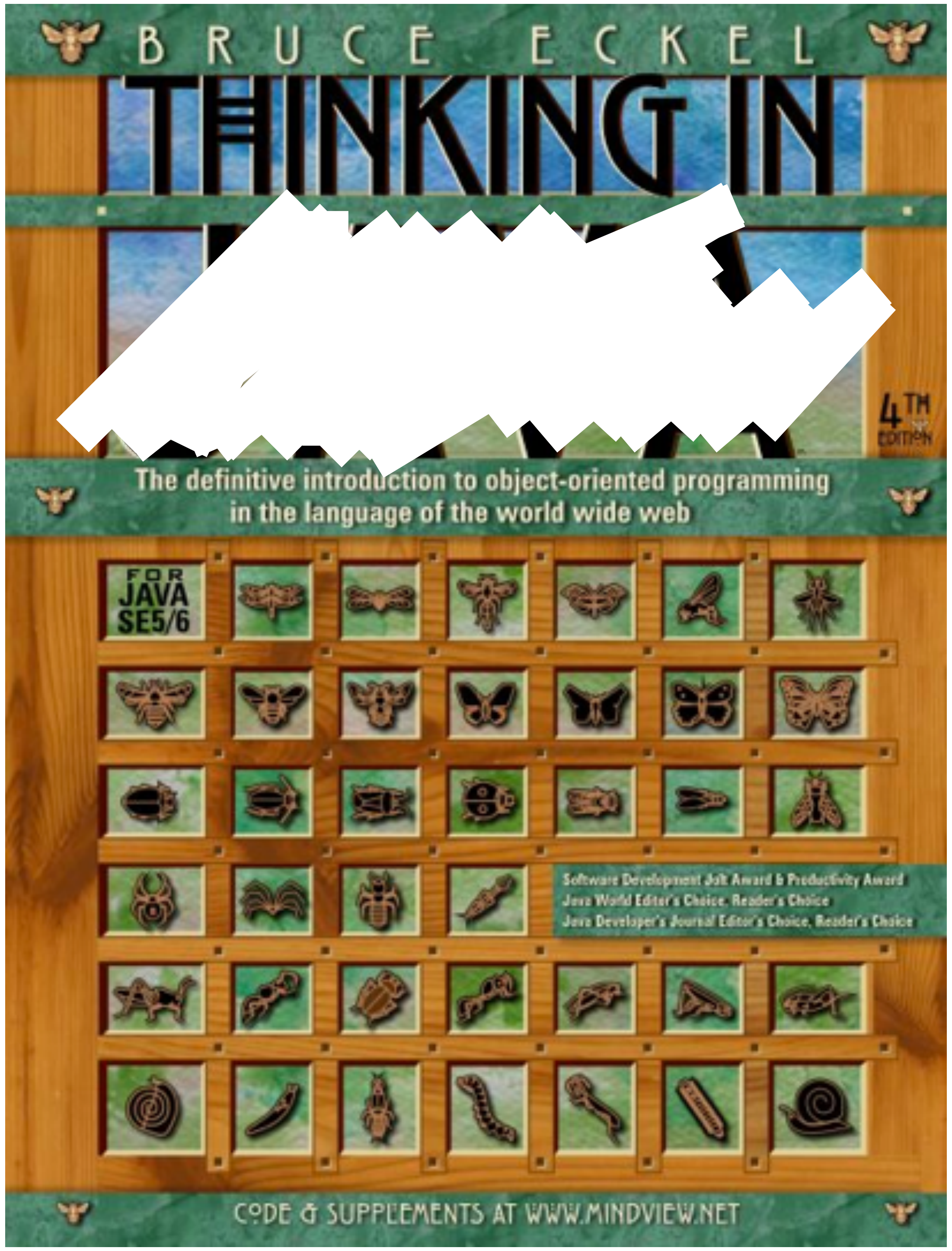
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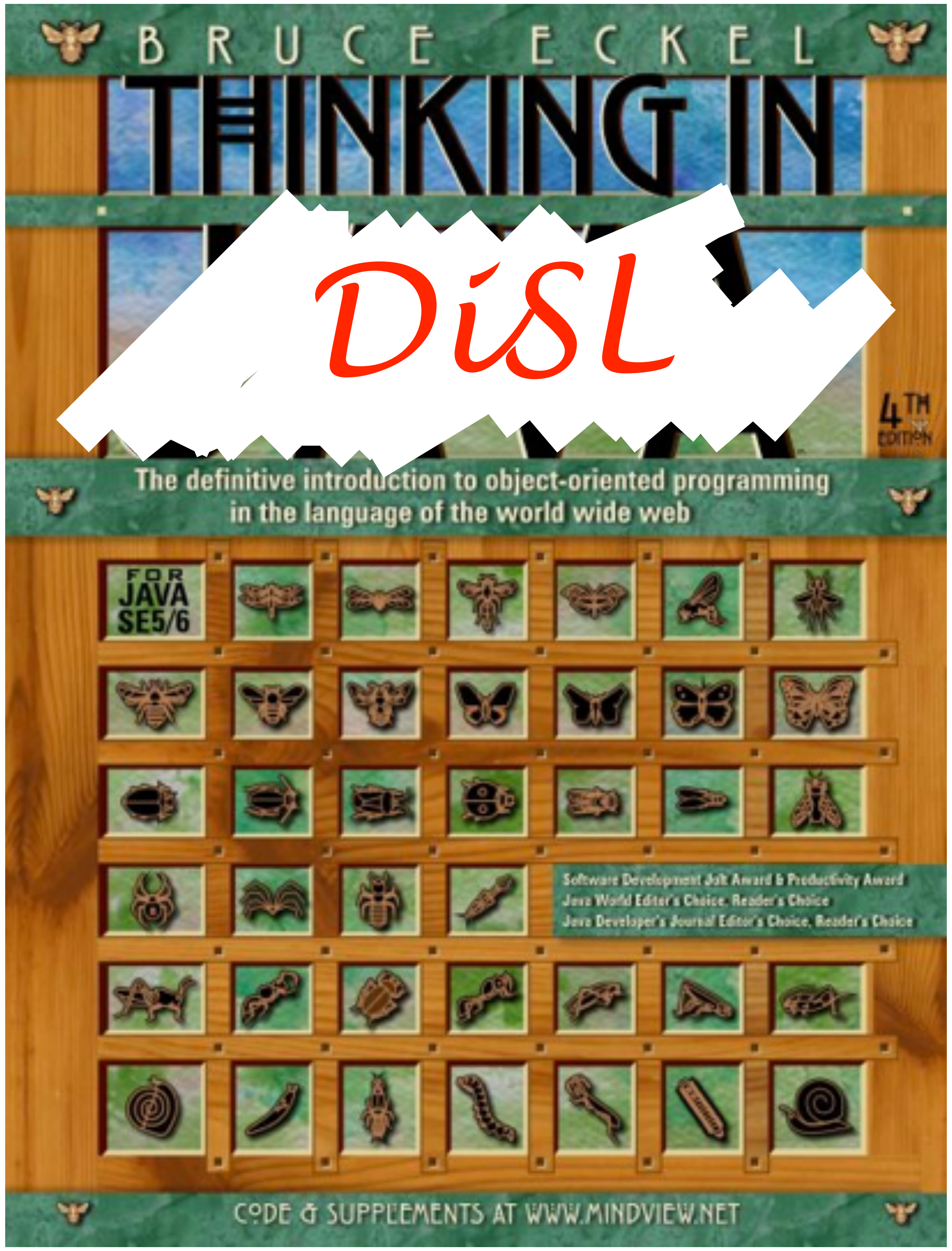
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Thinking in **DiSL**

Thinking in DiSL

1. **Event Producer/Consumer**

1. Event Producer/Consumer

Target Code

```
public static void main(String[] args) {
  System.out.println("Hello, world");
}
```

Thinking in DiSL

1. Event Producer/Consumer

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Thinking in **DiSL**

1. Event Producer/Consumer

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Runtime Analysis

```
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           firePremainEvent() {
      ...
   }
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```

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Thinking in **DiSL**

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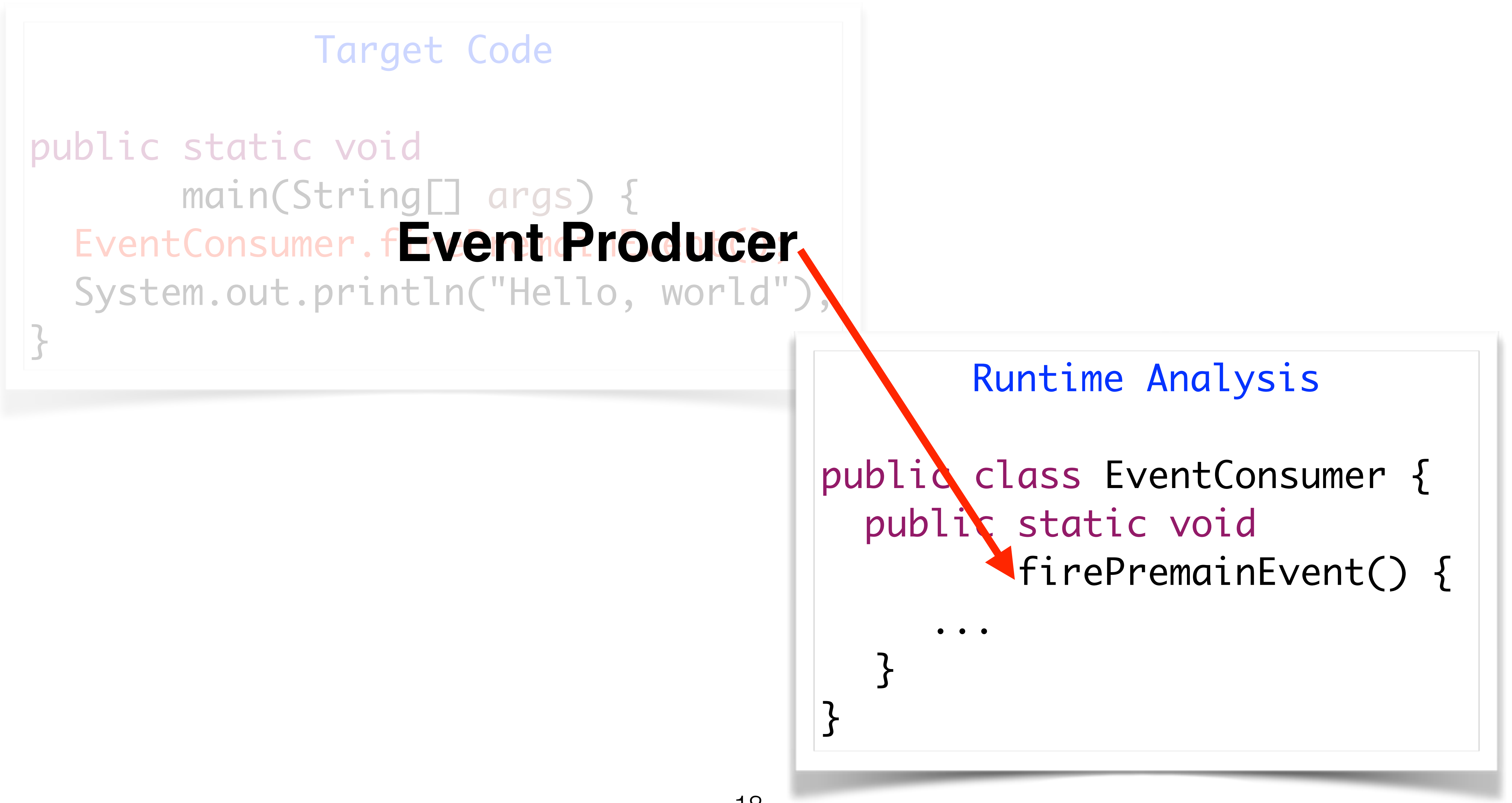

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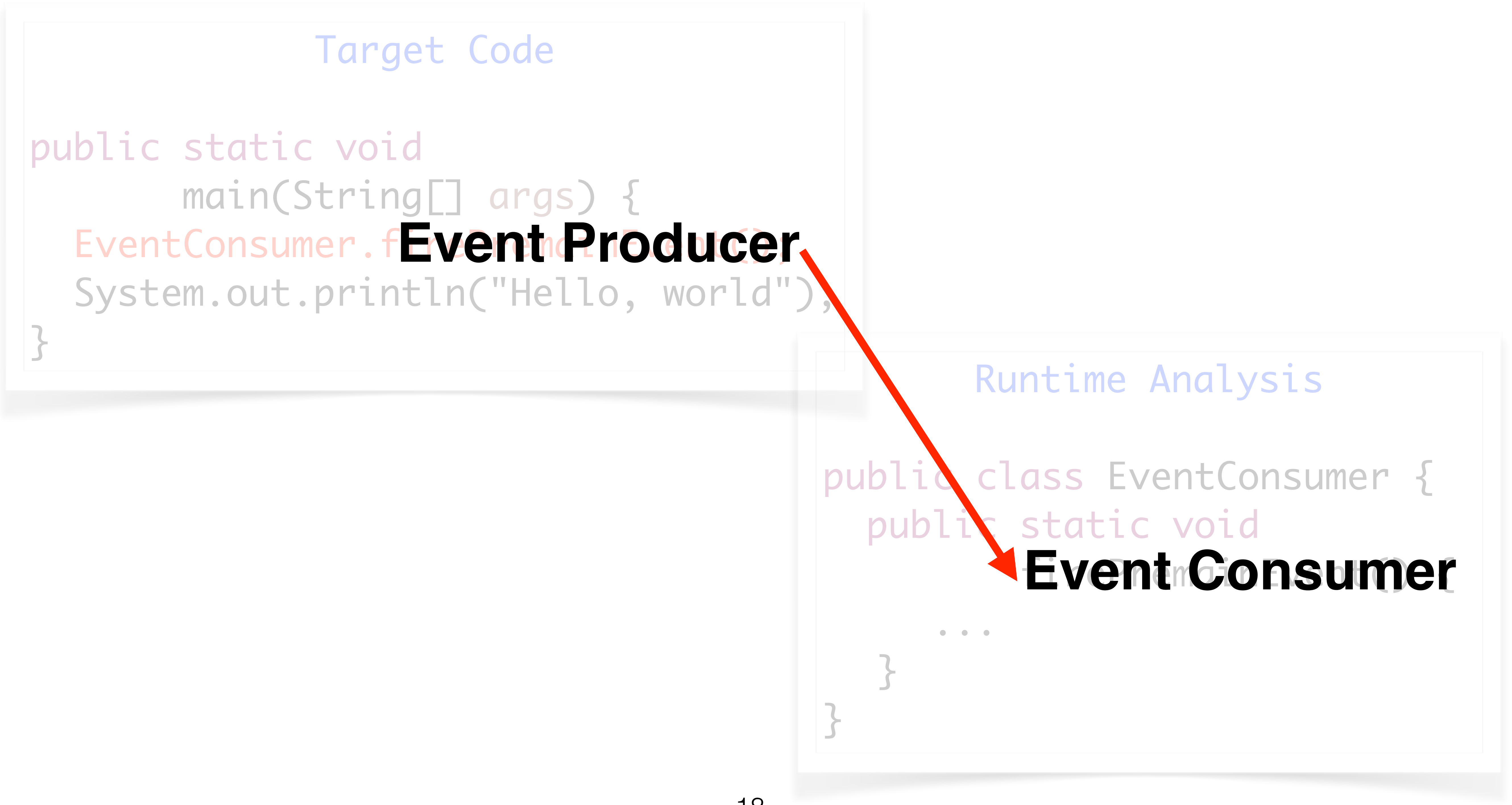
Thinking in DiSL

1. Event Producer/Consumer



```
public static void
      main(String[] args) {
  EventConsumer.fireDomainEvent();
  System.out.println("Hello, world");
}
```

```
public class EventConsumer {
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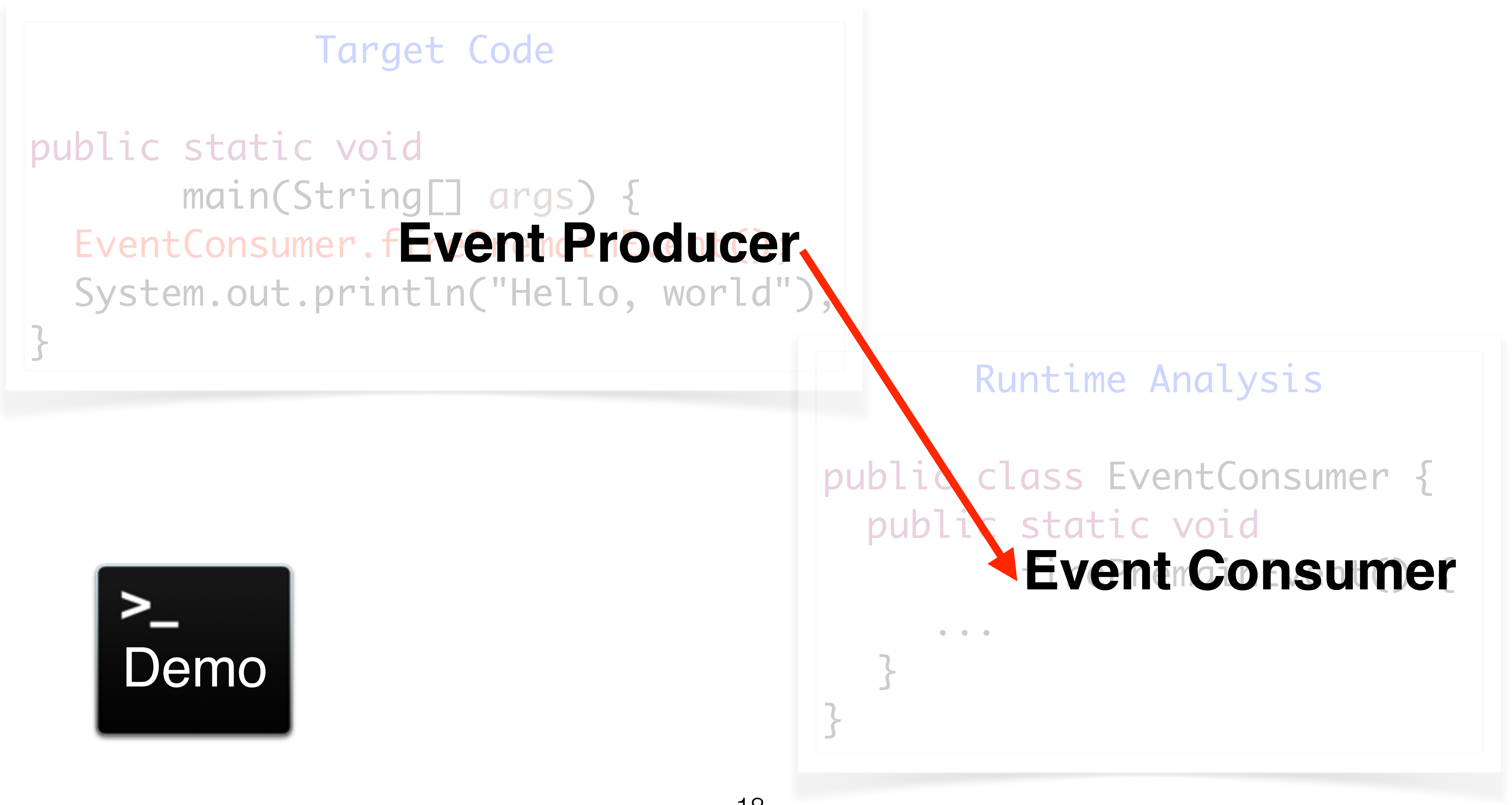
     ...
  }
}
```

Thinking in **DiSL**

1. Event Producer/Consumer



Target Code

```
public static void
      main(String[] args) {
  EventConsumer.firePreMainEvent();
  System.out.println("Hello, world");
}
```

Runtime Analysis

```
public class EventConsumer {
  public static void
          firePreMainEvent() {
     ...
  }
}
```

>_
Demo

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Example: Allocation Profiler

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- Count the number of allocations (**new** bytecode)

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Demo

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Demo

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>_ Demo

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Demo

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    - *Concurrent Event Handling*

>_
Demo

2. Concurrent Event Handling

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Target Code

```
private static void foo() {
  for (int i = 0; i < 2000; i++) {
    new Object();
    Profiler.fireEvent();
  }
}
```

2. Concurrent Event Handling

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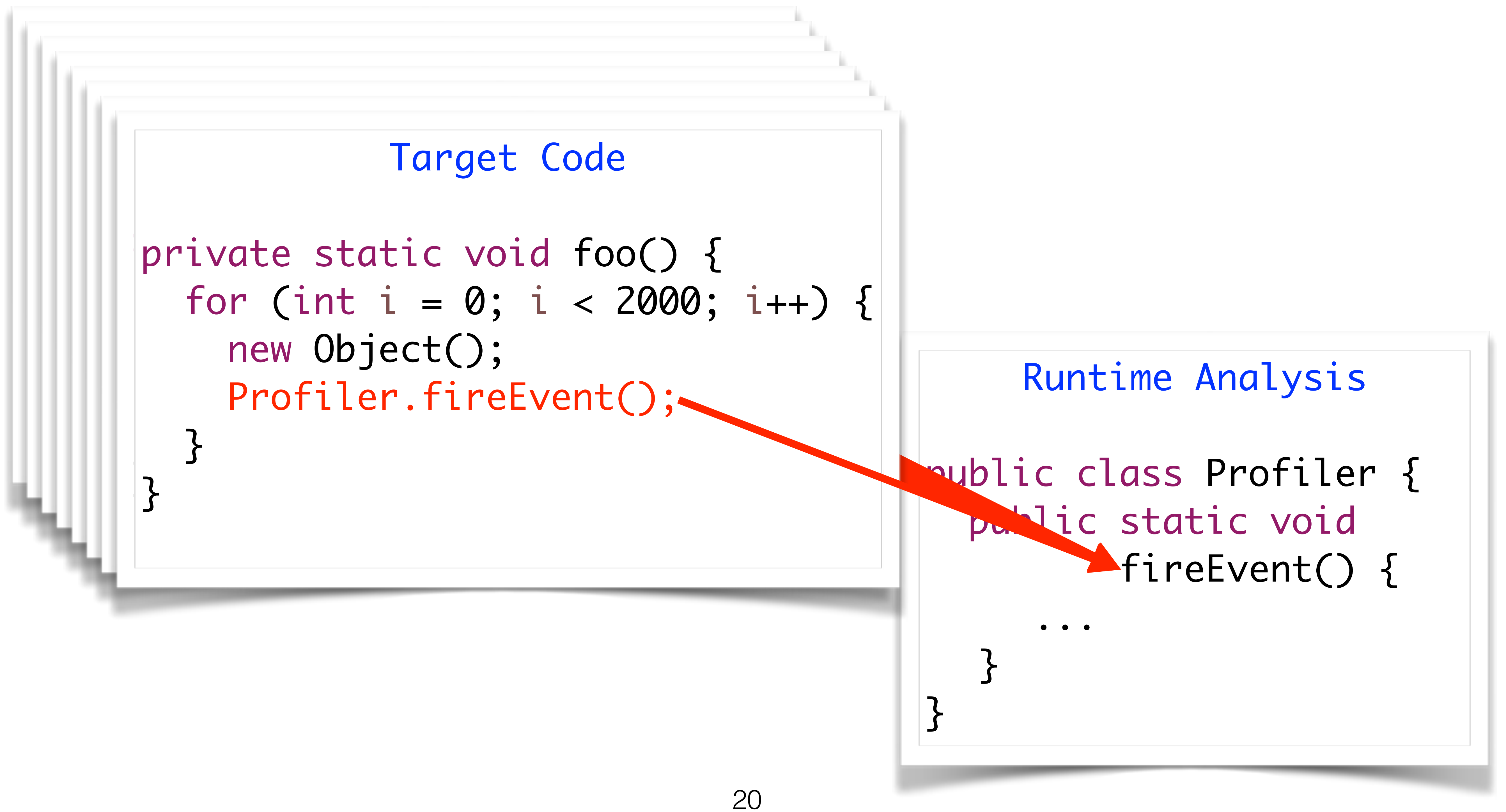

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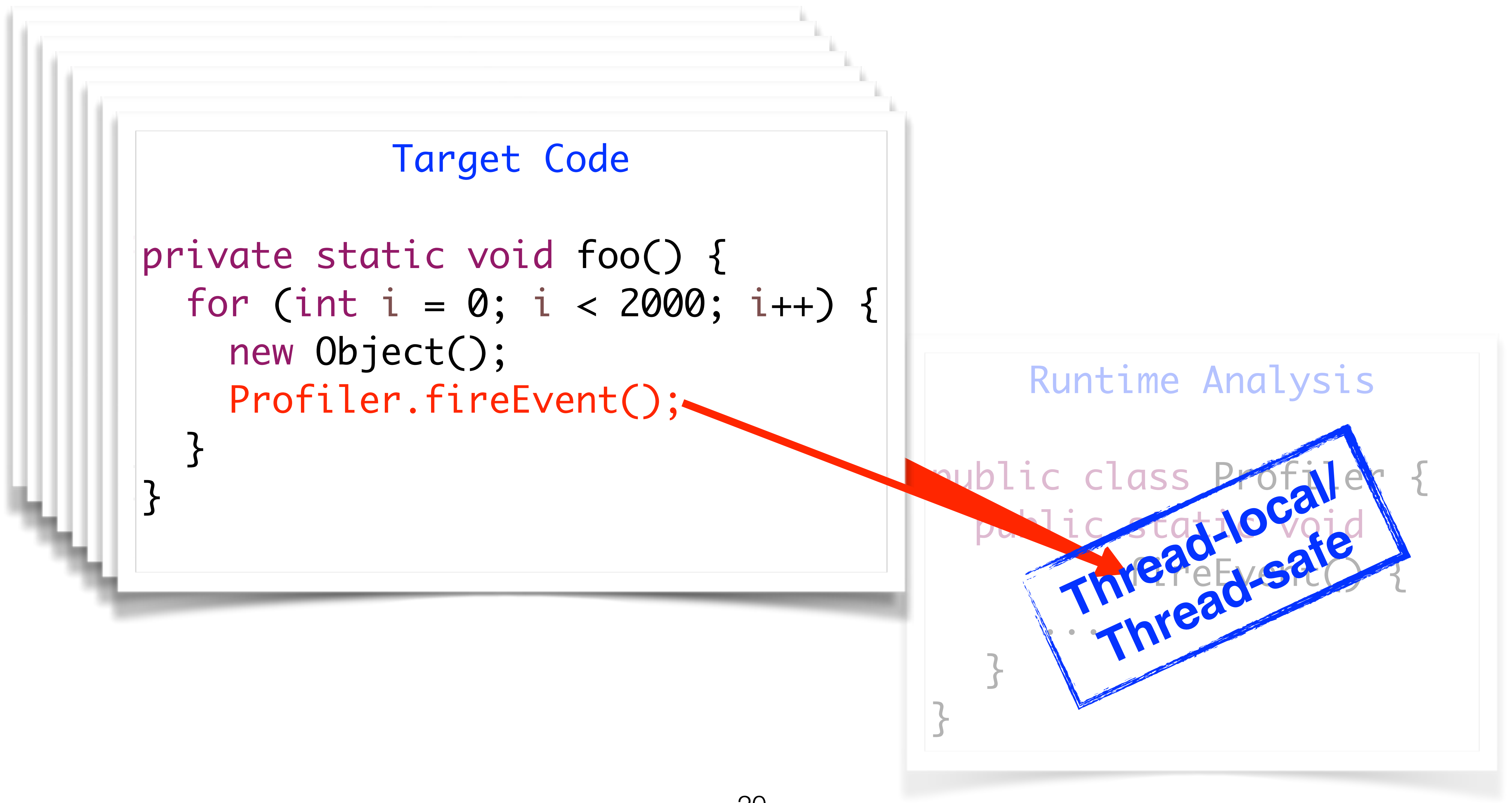

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Thinking in DiSL

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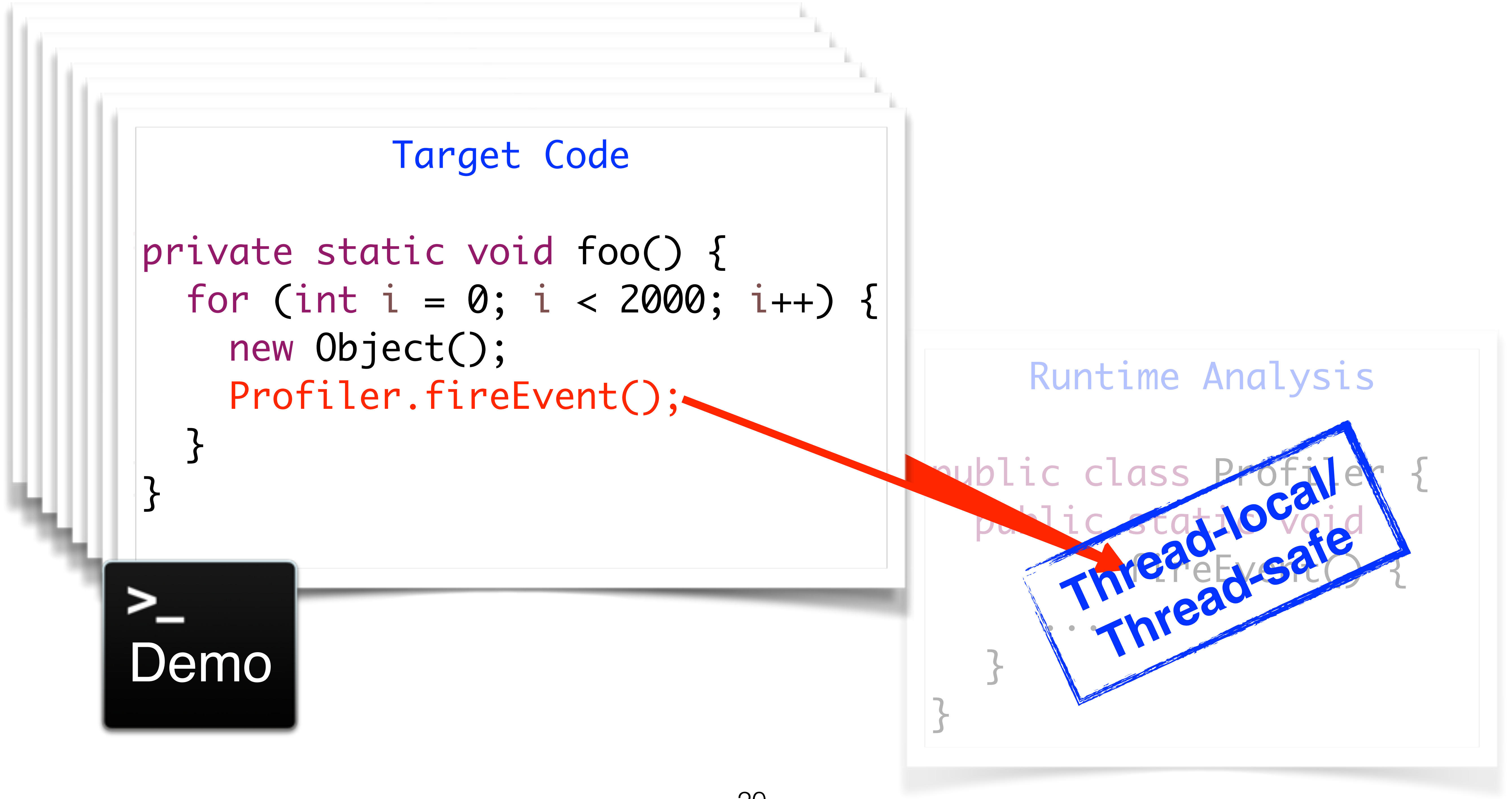

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>_ Demo

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- Synchronized event handler

2. Concurrent Event Handling

Runtime Analysis

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      ...
  }
}
```

- Synchronized event handler
- Thread-local data structure

2. Concurrent Event Handling

```
     Runtime Analysis

public class Profiler {
  public static void
         fireEvent() {
      ...
  }
}
```

- Synchronized event handler
- Thread-local data structure
- Concurrent data structure

Example: Allocation Profiler

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- Re-implement using thread-local data structure

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Demo

Example: Allocation Profiler

- Re-implement using thread-local data structure
  - No locking during event handling (except initialization)
- Re-implement using concurrent data structure
  - Lock-free data structure
  - Test with multi-threaded program running **different** methods
- How do we express the instrumentation?

>_ Demo

Thinking in **DiSL**

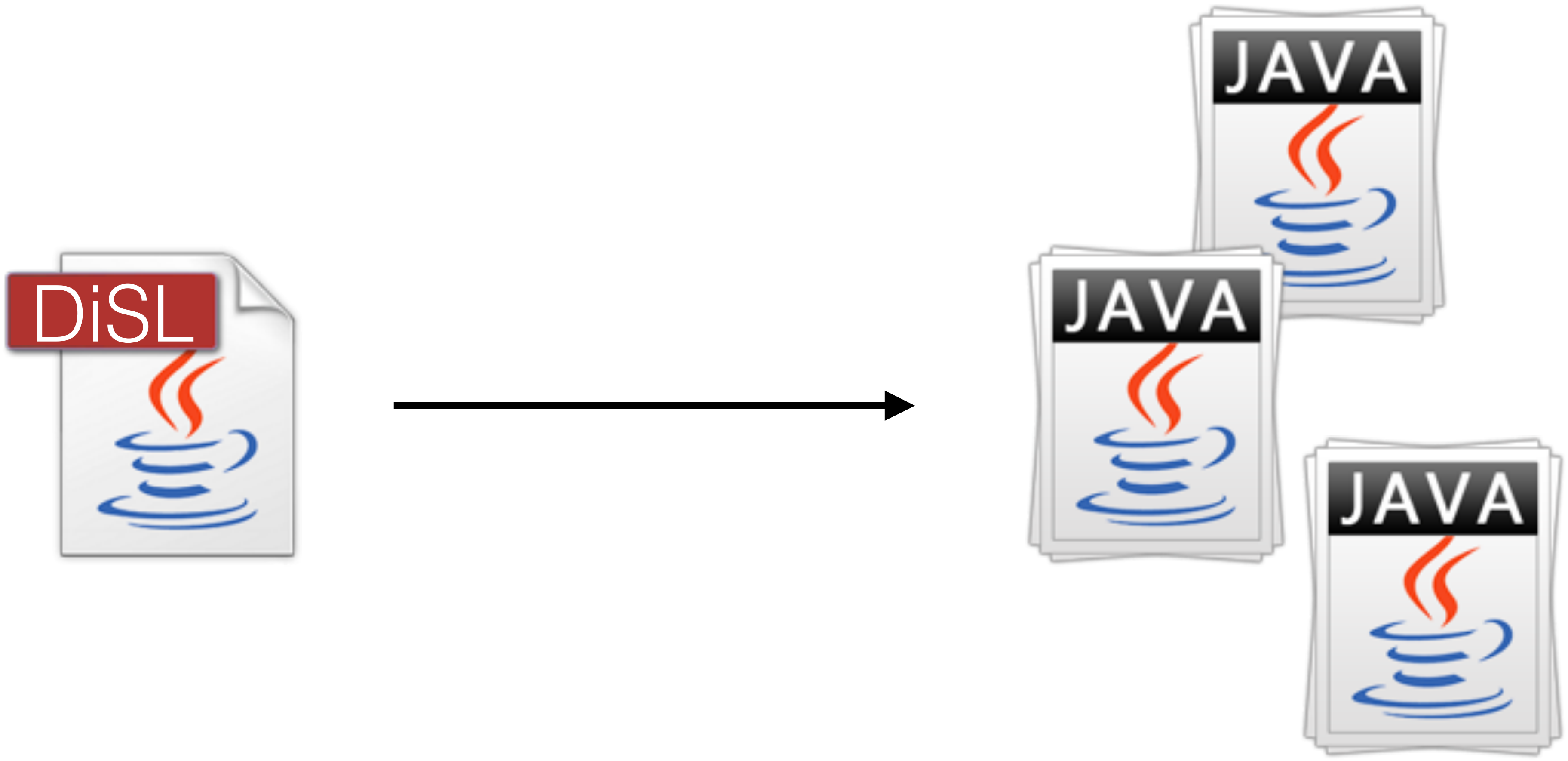
3. Aspect-Oriented

Thinking in **DiSL**

3. **Aspect-Oriented**

Thinking in DiSL

3. **Aspect-Oriented**



Thinking in **DiSL**

*Annotation: describes **where** to instrument*

```
@AfterReturning(marker = BytecodeMarker.class,
                args = "new",
                scope = "AllocationTest.foo")
static void profile() {
  Profiler.fireEvent();
}
```

*Method Body: describes **what** to instrument*

Thinking in DiSL

Marks the interested program behavior

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@AfterReturning(marker = BytecodeMarker.class,
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                scope = "AllocationTest.foo")
static void profile() {
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```
goto LOOP_START
new java.lang.Object
invokespecial java.lang.Object()
```

Thinking in DiSL

Marks the interested program behavior

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                args = "new",
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Thinking in DiSL

Marks the interested program behavior

```
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                args = "new"  |- BodyMakrer.class
                scope = "A|- BasicBlockMarker.class
static void profile() {   |- TryClauseMarker.class
  Profiler.fireEvent();   |- ExceptionHandlerMarker.class
}
```

Thinking in **DiSL**

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@AfterReturning(marker = BytecodeMarker.class,
                args = "new"|- BodyMakrer.class
                scope = "All|- BasicBlockMarker.class
static void profile() {  |- TryClauseMarker.class
  Profiler.fireEvent();  |- ExceptionHandlerMarker.class
}                        |
                         |- <T extends Marker>
                            (Requires ASM knowledge)
```

Thinking in **DiSL**

Defines the relevant position of the instrumentation

```
@AfterReturning(marker = BytecodeMarker.class,
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Thinking in DiSL

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Thinking in **DiSL**

```
@AfterReturning
|- @Before
|- @AfterThrowing
|- @After
```

```
@AfterReturning(marker = BytecodeMarker.class,
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                 scope = "AllocationTest.foo")
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```

Thinking in **DiSL**

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|- @AfterThrowing
|- @After
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@AfterReturning(marker = BytecodeMarker.class,
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Thinking in DiSL

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@AfterReturning(marker = BytecodeMarker.class,
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|- @AfterThrowing scope = "AllocationTest.foo")
|- @After
static void profile() {
  Profiler.fireEvent();
}
```

```
goto LOOP_START
try {
new java.lang.Object
} catch (Throwable e) {
  Profiler.fireEvent();
}
invokespecial java.lang.Object()
```

Thinking in **DiSL**

```
@AfterReturning(marker = BytecodeMarker.class,
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|- @Before
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Thinking in **DiSL**

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@AfterReturning(marker = BytecodeMarker.class,
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static void profile() {
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}
```

```
|- @Before
|- @AfterThrowing
|- @After
```

```
goto LOOP_START
try {
new java.lang.Object
} finally {
  Profiler.fireEvent();
}
invokespecial java.lang.Object()
```

Thinking in **DiSL**

Selects methods to instrument

```
@AfterReturning(marker = BytecodeMarker.class,
                args = "new",
                scope = "AllocationTest.foo")
static void profile() {
  Profiler.fireEvent();
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```

Thinking in **DiSL**

Selects methods to instrument

```
@AfterReturning(marker = BytecodeMarker.class,
                args = "new",
                scope = "*.*"AllocationTest.foo")
static void profile() {
  Profiler.fireEvent();
}
```

Thinking in DiSL

```
@AfterReturning(marker = BytecodeMarker.class,
                args = "new",
                guard = SomeGuard.class.foo")
static void profile() {
  Profiler.fireEvent();
}
```

Alternative way of selection.

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Thinking in DiSL

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@AfterReturning(marker = BytecodeMarker.class,
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Alternative way of selection.

1. contains an @GuardMethod returning a boolean.

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Thinking in DiSL

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@AfterReturning(marker = BytecodeMarker.class,
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Alternative way of selection.

1. contains an @GuardMethod returning a boolean.
2. has access to static contextual information.

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Thinking in **DiSL**

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@AfterReturning(marker = BytecodeMarker.class,
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Alternative way of selection.

1. contains an @GuardMethod returning a boolean.
2. has access to static contextual information.

(demo later)

Still With Me?

Thinking in DiSL

```
@AfterReturning(marker = BytecodeMarker.class,
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static void profile() {
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```

Thinking in **DiSL**

```
@AfterReturning(marker = BytecodeMarker.class,
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static void profile() {
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Will be inserted everywhere.

Thinking in DiSL

```
@AfterReturning(marker = BytecodeMarker.class,
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Will be inserted everywhere.

But where exactly?

Thinking in DiSL

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But where exactly?

Answer: depends on the instrumentation location.

Thinking in DiSL

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Will be inserted everywhere.

But where exactly?

Answer: depends on the instrumentation location.

Solution: synthetic method call that represents

Contextual Information

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Contextual Information

Contextual Information

- Dynamic contextual information

Contextual Information

- Dynamic contextual information
    - cannot be resolved until execution.

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    - cannot be resolved until execution.
    - e.g., receiver of an invocation, argument to a method

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```
@Before(marker = BodyMarker.class,
        scope = "java.lang.ProcessImpl.start")
static void onNewProcess(DynamicContext dc) {
  String[] cmd = (String[])
                 dc.getMethodArgumentValue(0, Object.class);
  System.out.println(Arrays.toString(cmd));
}
```

Contextual Information

- Dynamic contextual information

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final class ProcessImpl {
  static Process start(String[] cmdarray,
                                 ...) throws IOException {
    assert cmdarray != null && cmdarray.length > 0;
```

Contextual Information

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  - **[clarify]** DiSL targets Java bytecode, where the variable name may not be available; it uses numeric index and relies on the user for the correct input.

Contextual Information

- Dynamic contextual information
  - **[clarify]** DiSL targets Java bytecode, where the variable name may not be available; it uses numeric index and relies on the user for the correct input.
  - Advanced interface methods require deep understanding of Java Virtual Machine, e.g, `DynamicContext.getStackValue()`

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Contextual Information

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  - customizable (requires ASM knowledge)
  - can be used in @GuardMethod

Example: Allocation Profiler

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- Group allocation profile by method name

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@AfterReturning(marker = BytecodeMarker.class,
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static void foo() {
  for (int i = 0; i < 2000; i++) {
    new Object();
  }
}
```

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```

>_
Demo

Example: mvn

- Instrument method annotated by @Test

```
public class GuardUnitTest {
  @GuardMethod
  public static boolean
              isApplicable(AnnotationContext context) {
    return context.annotatedByTest();
  }
}

public class AnnotationContext
              extends MethodStaticContext {
  public boolean annotatedByTest() {
    ... // code using ASM
  }
}
```

Example: mvn

- Instrument method annotated by @Test

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public class GuardUnitTest {
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         isApplicable(AnnotationContext context) {
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       extends MethodStaticContext {
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  }
}
```

>_ Demo

Other **DiSL** Features

- @SyntheticLocal: share data between different instrumentation at the same method
- @ThreadLocal: append a field in java.lang.Thread
- Argument Processor
  - Single code snippet to process arguments of the same type

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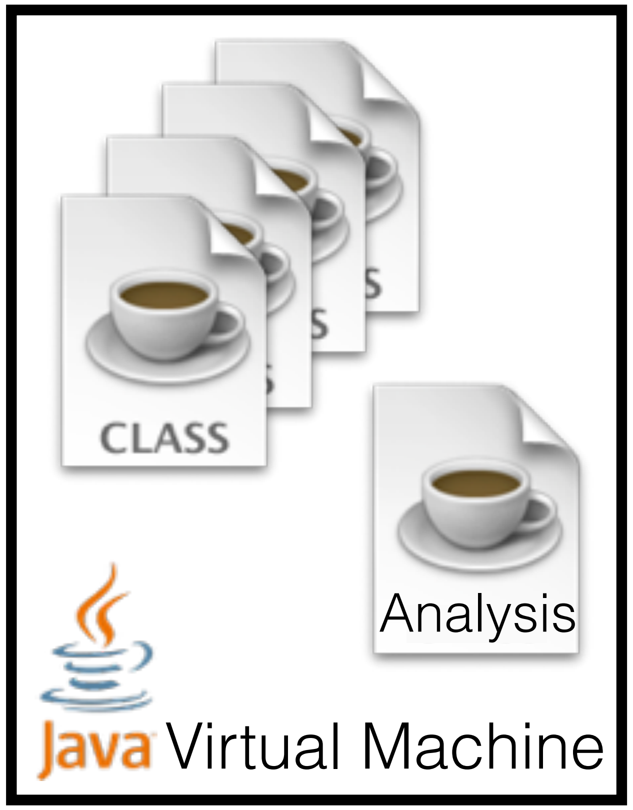
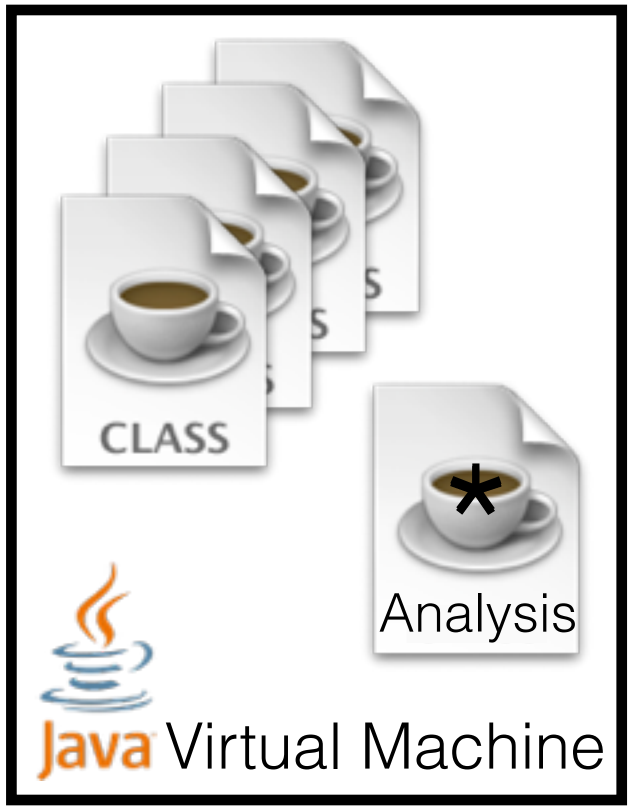
Projects Derived From DiSL

ShadowVM



In-process Analysis

ShadowVM



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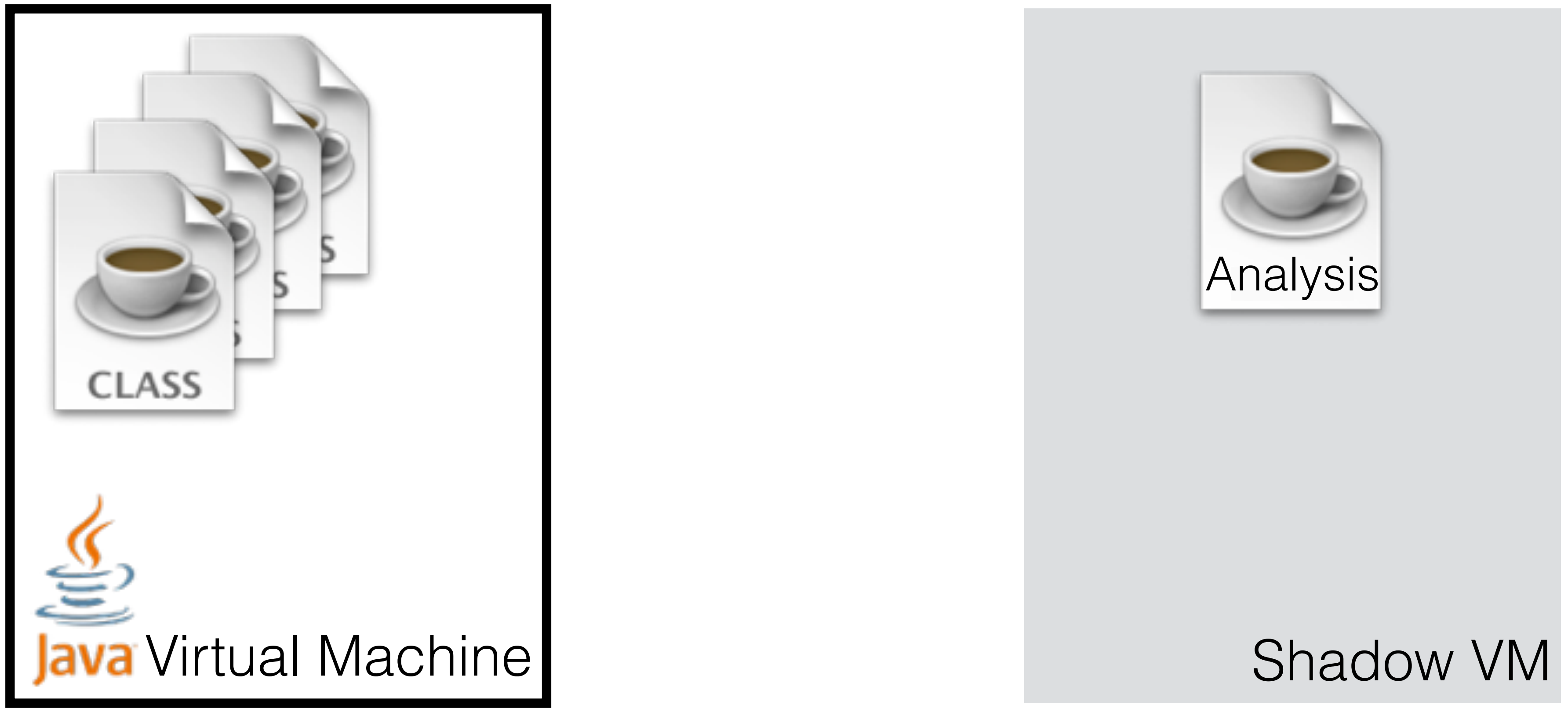
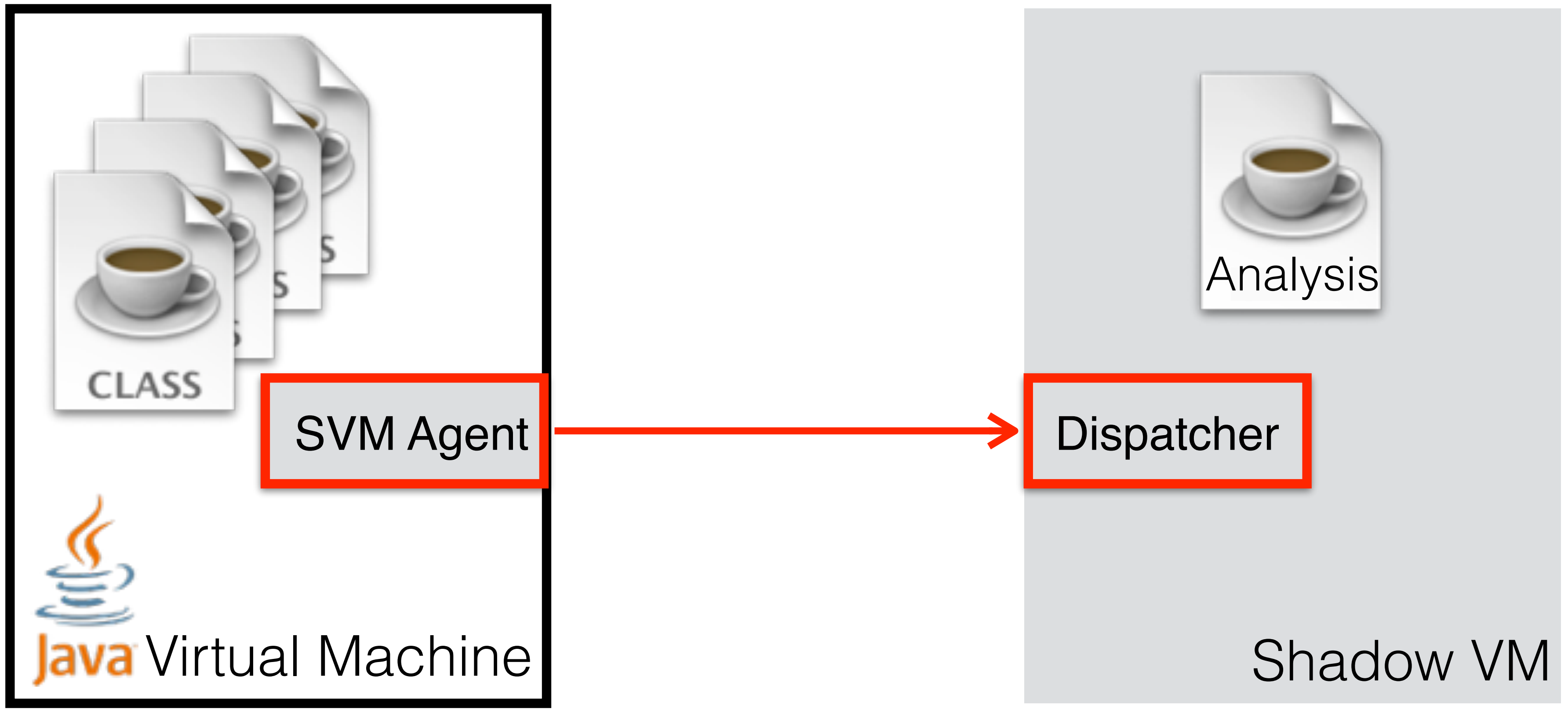


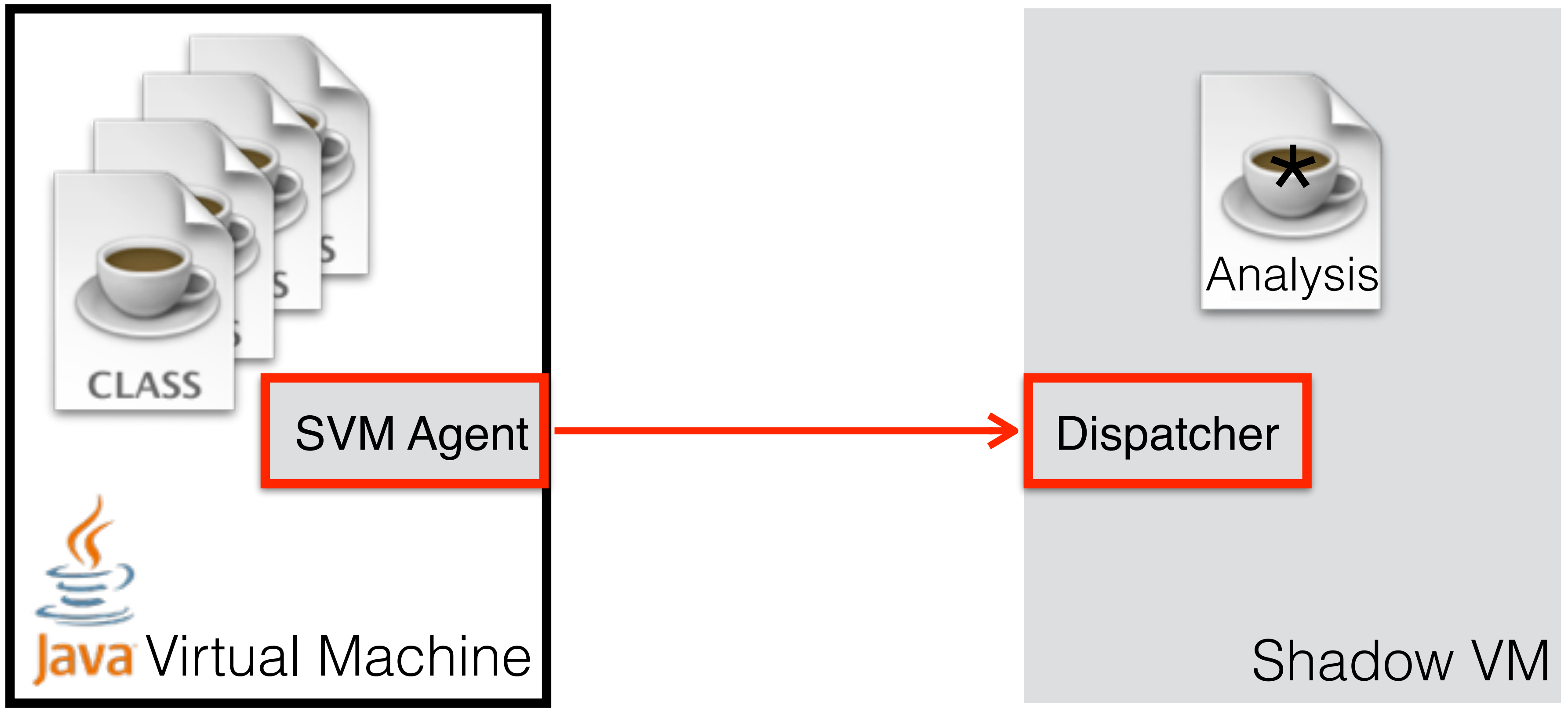
ShadowVM Analysis

ShadowVM



ShadowVM Analysis

ShadowVM



ShadowVM Analysis

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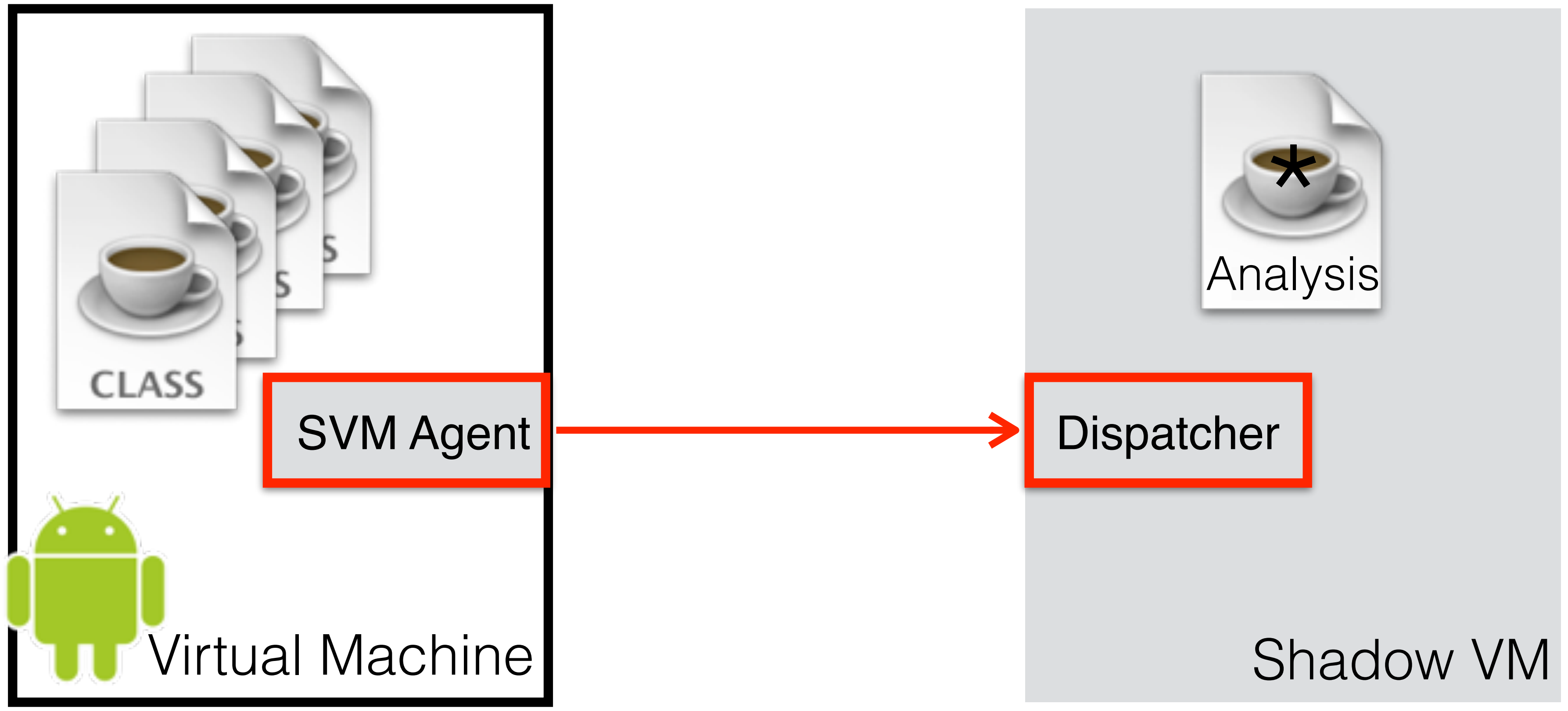
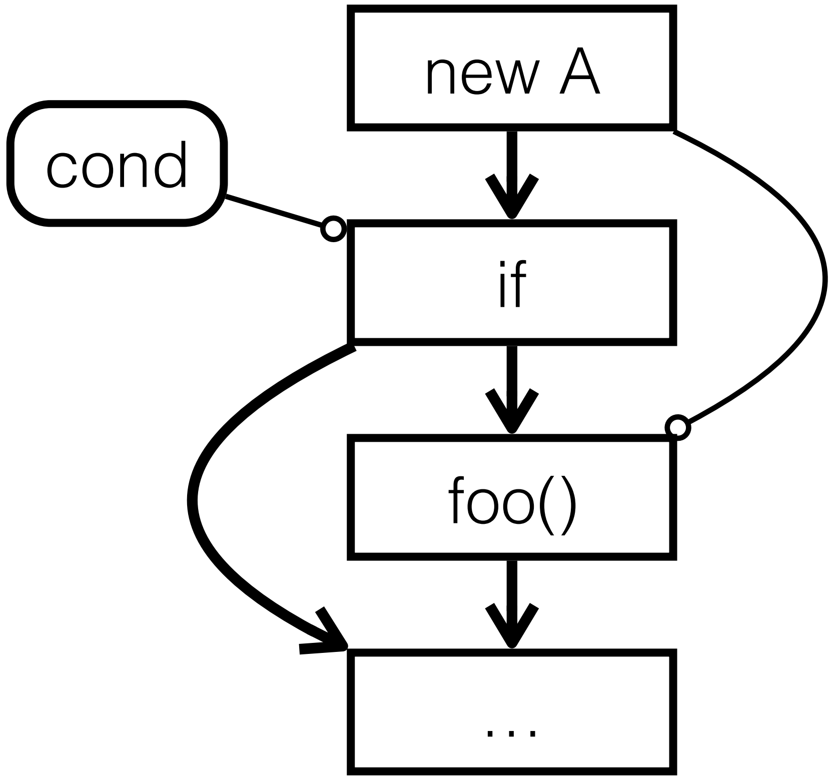


ShadowVM Analysis

Accurate Profiling - The Problem

```
A a = new A();
if (cond) { // 10% taken
   a.foo(); // a escapes
}
```



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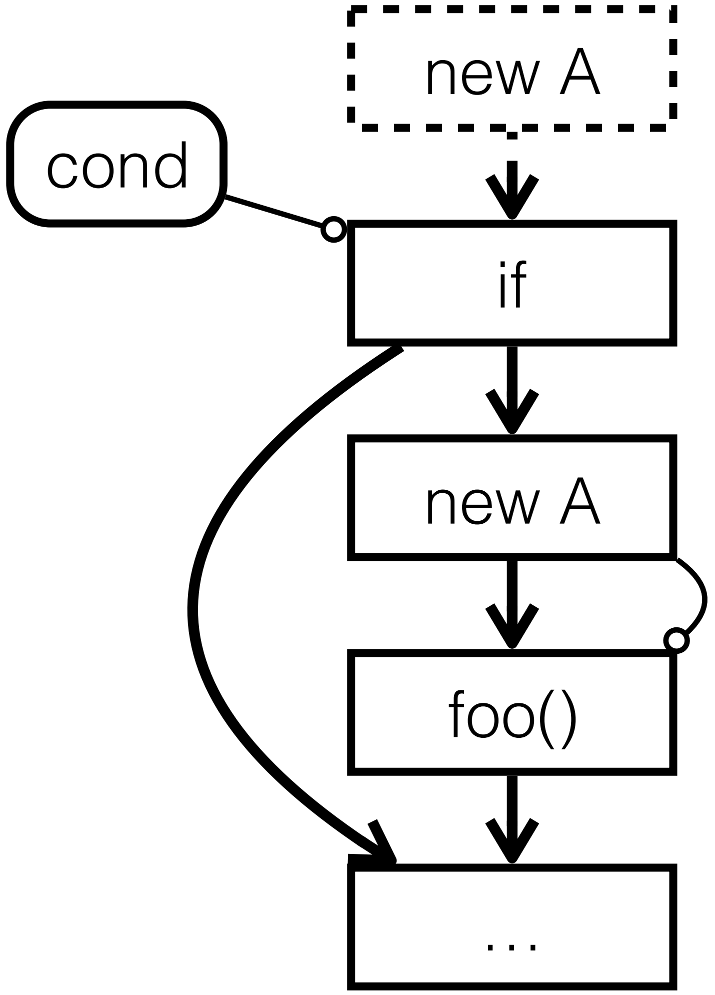
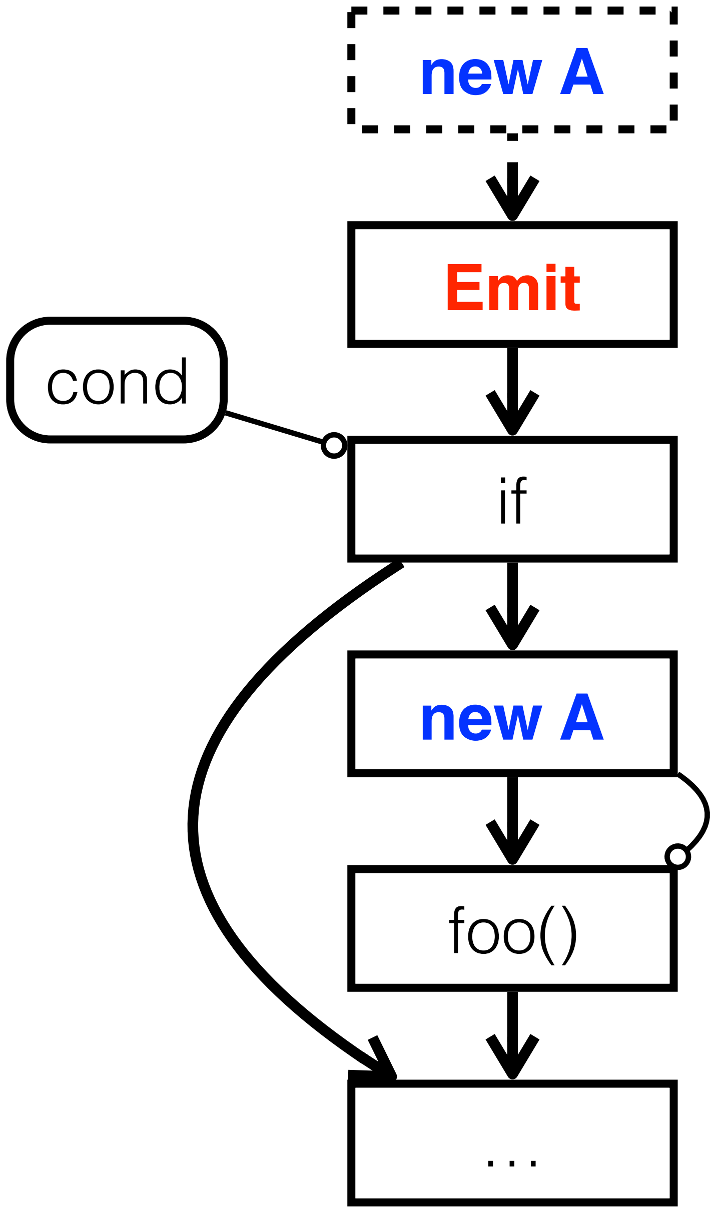


* Lukas Stadler, Thomas Würthinger, Hanspeter Mössenböck. Partial Escape Analysis and Scalar Replacement for Java. CGO '14

Accurate Profiling - The Problem

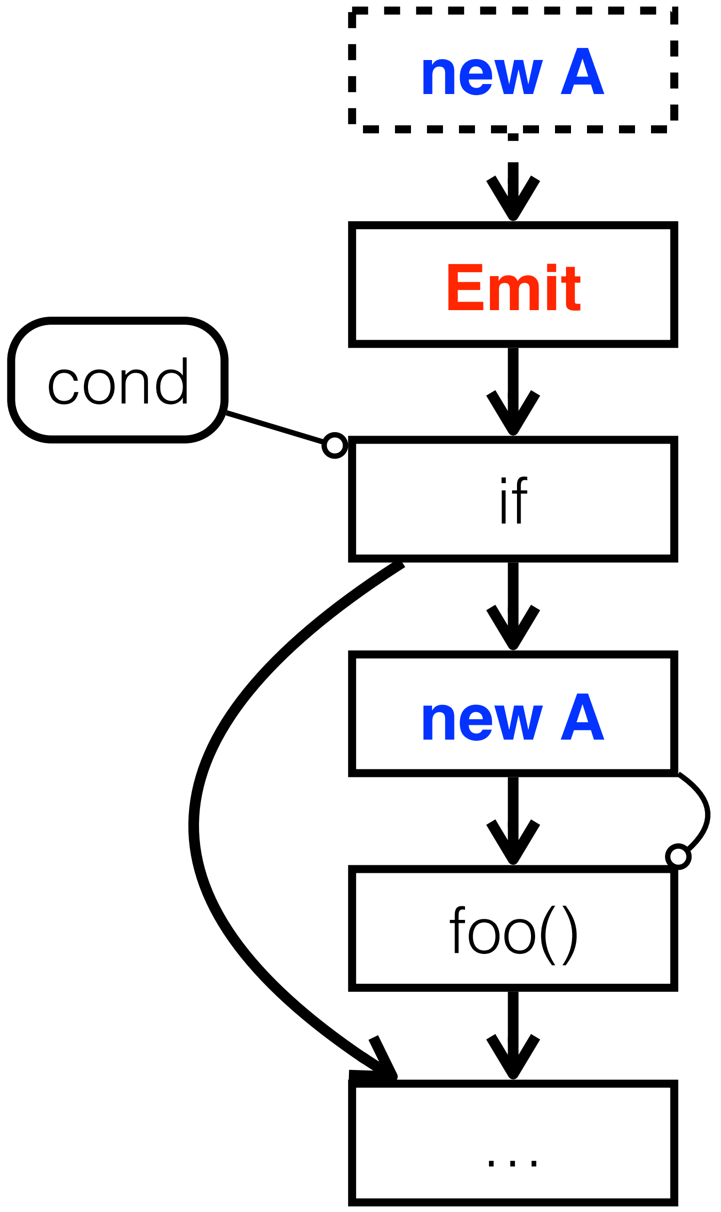
```
A a = new A();
EmitAllocEvent();
if (cond) { // 10% taken
   a.foo(); // a escapes
}
```



Accurate Profiling - The Problem

```
A a = new A();
EmitAllocEvent();
if (cond) { // 10% taken
   a.foo(); // a escapes
}
```

For 1000 executions of the code snippet:
  Actual Allocations: 100
  Intercepted Allocations: 1000
  Without-instrumentation: 100



Accurate Profiling - The Problem

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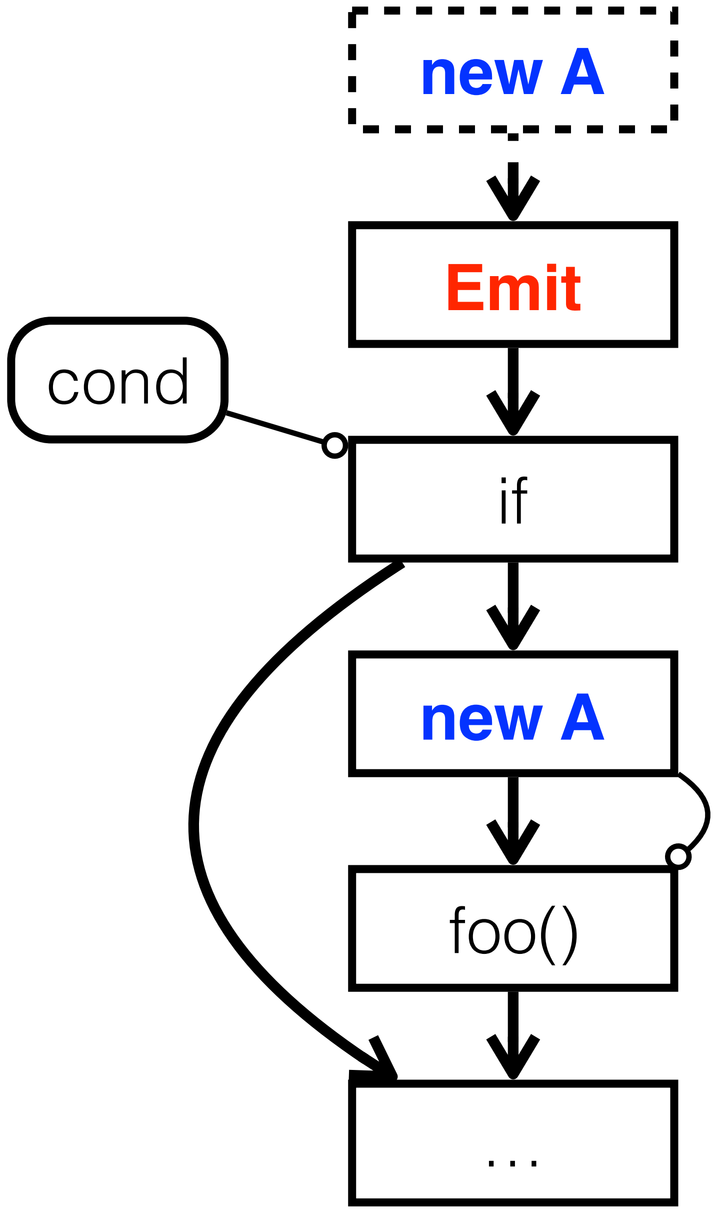
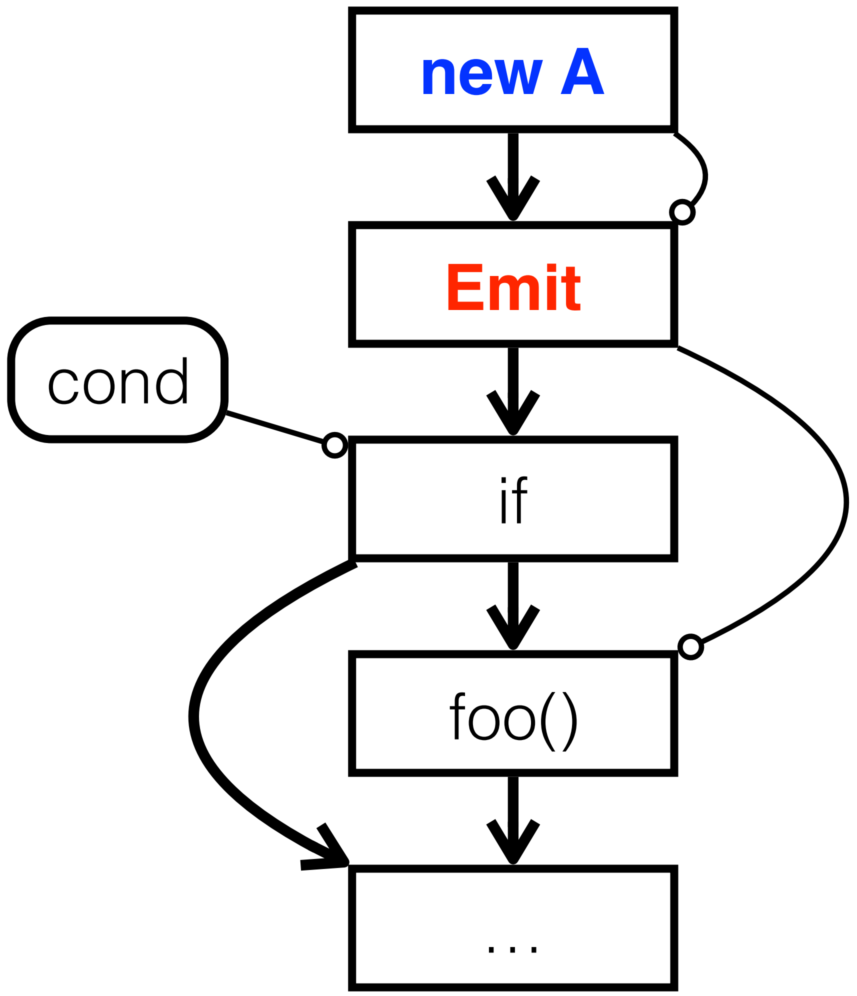
OVER-PROFILED



Accurate Profiling - The Problem

```
A a = new A();
EmitAllocEvent(a);
if (cond) { // 10% taken
   a.foo(); // a escapes
}
```



Accurate Profiling - The Problem

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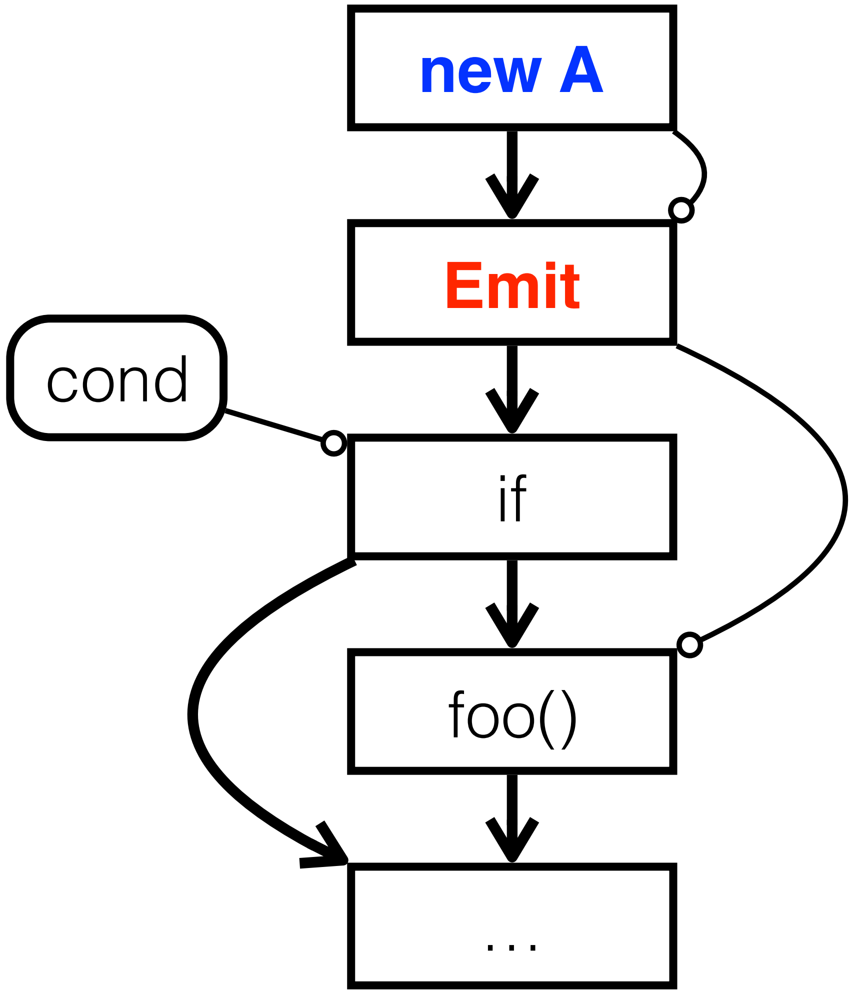

For 1000 executions of the code snippet:
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Accurate Profiling - The Problem

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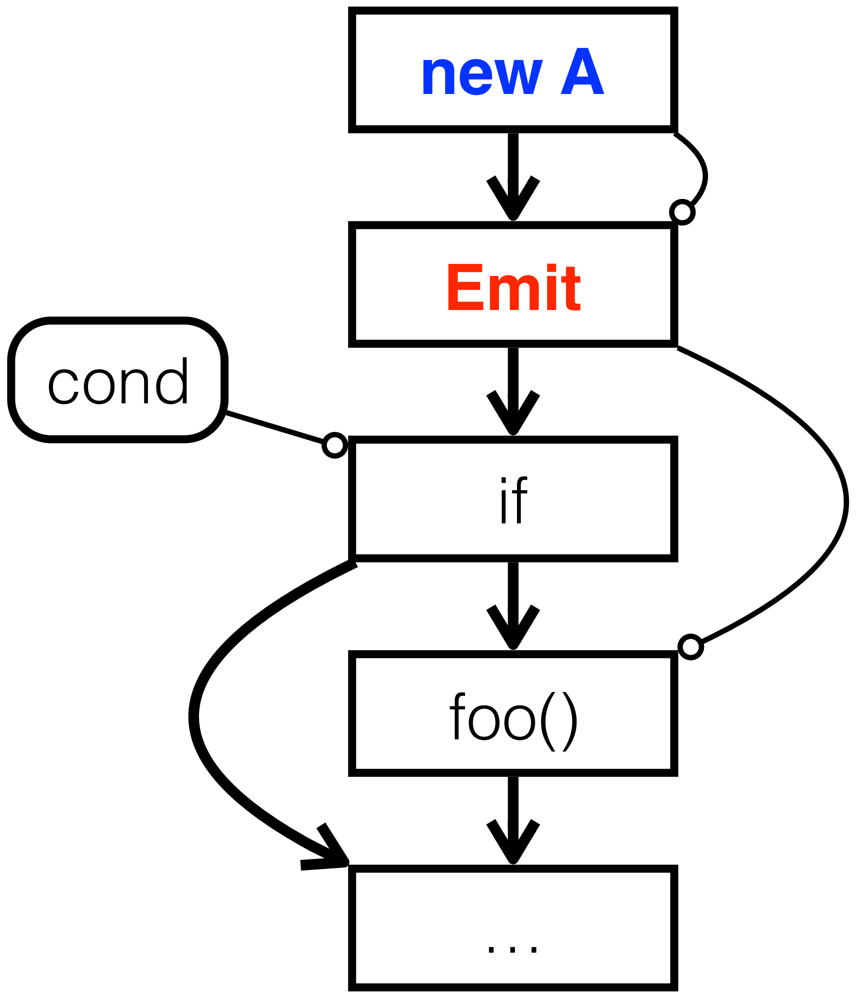

For 1000 executions of the code snippet:
  Actual Allocations: 1000
  Intercepted Allocations: 1000
  Without instrumentation: 100

OVER-PROFILED

Questions?

yudi.zheng@usi.ch
https://github.com/mur47x111/DiSLDemo

1. DiSL: a domain-specific language for bytecode instrumentation. AOSD '12
2. ShadowVM: robust and comprehensive dynamic program analysis for the java platform. GPCE '13
3. A programming model and framework for comprehensive dynamic analysis on Android. MODULARITY '15
4. Accurate profiling in the presence of dynamic compilation. OOPSLA '15