Extraction of Properties in C Implementations of Security APIs for Verification of Java Applications

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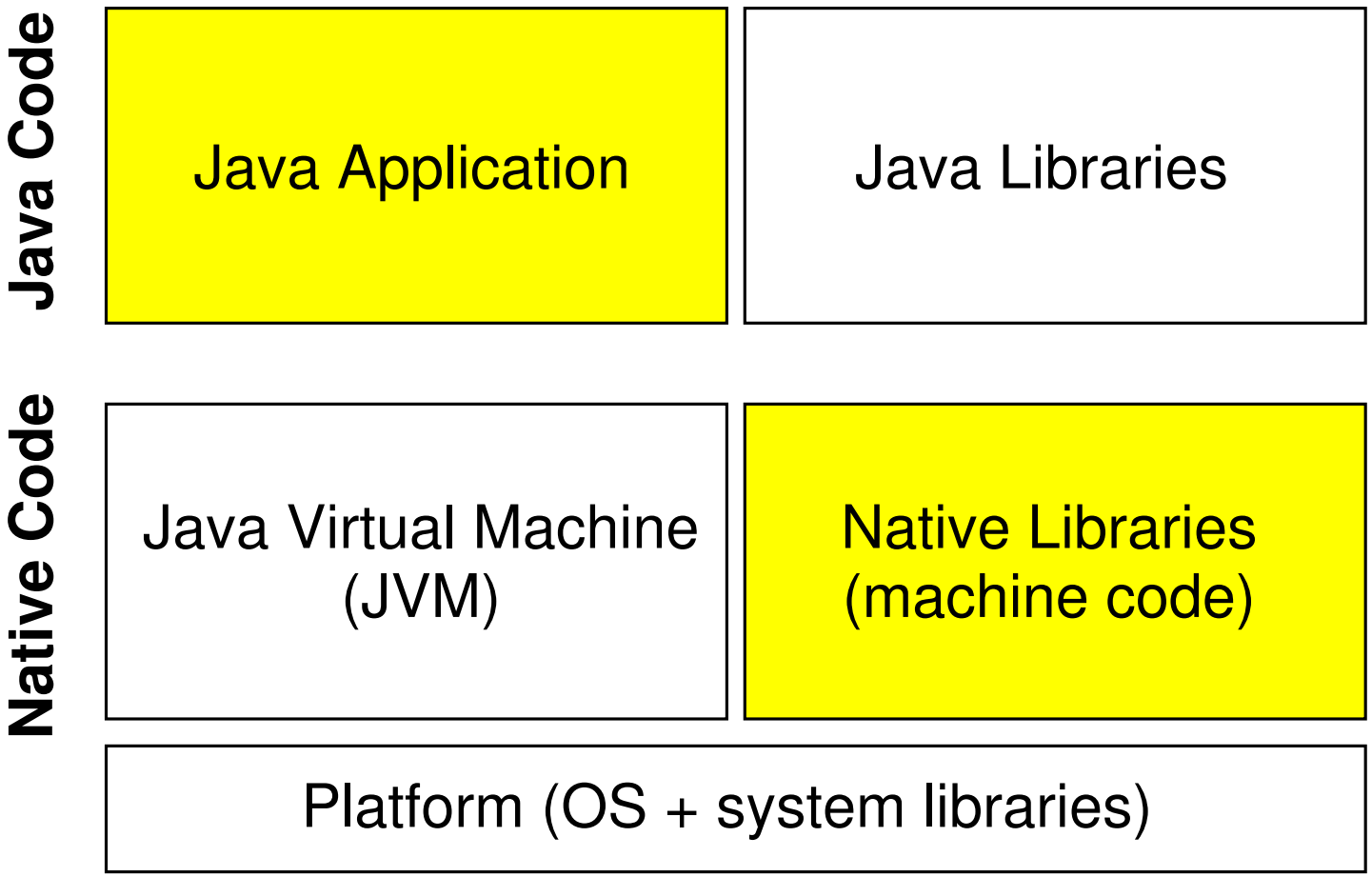
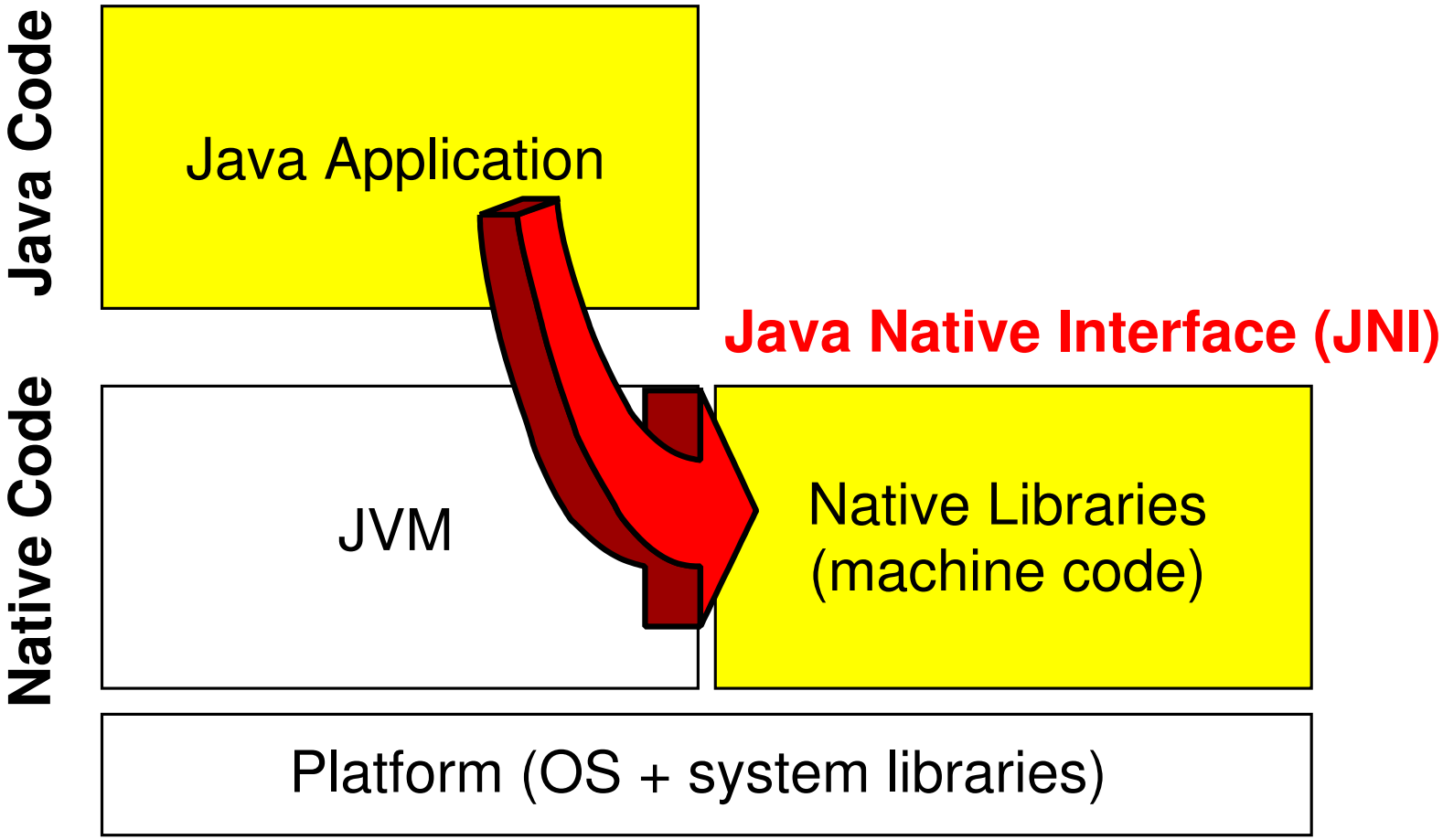
Anatomy of a Java application



Java code can interact with native libraries via Java Native Interface (JNI).

Java Native Interface (JNI)



Effects of JNI calls difficult to analyze!

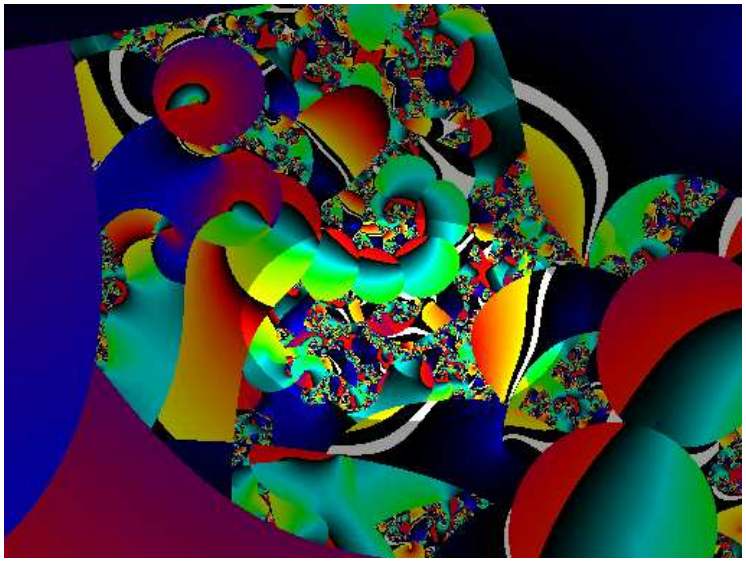
Overview

1. **Dynamic and static program analysis.**
2. Security properties in JNI code.
3. Bridging the gap between Java and native code.
4. Conclusion.

Dynamic and Static Analysis

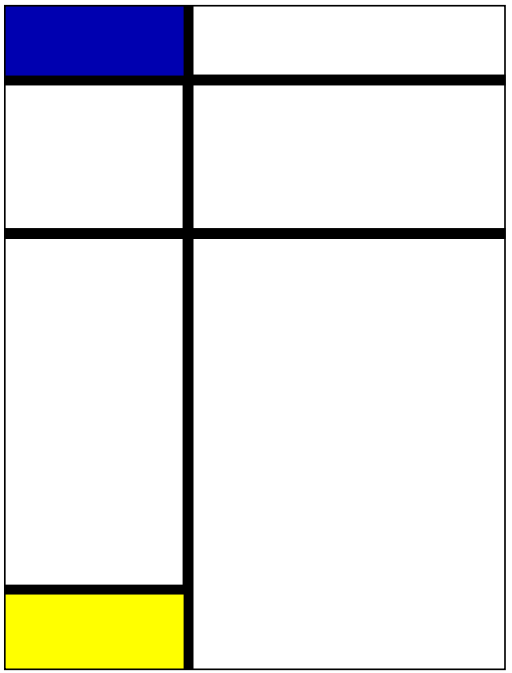
Dynamic Analysis

- “at run time”
- analyze real system



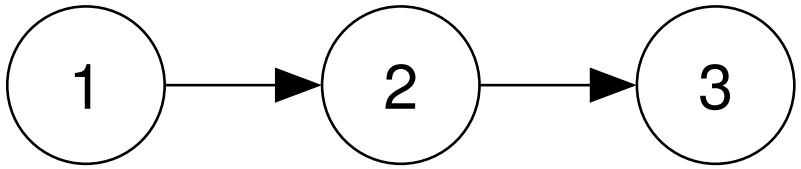
Static Analysis

- “at compile time’
- analyze simplified system (model)



Two divided worlds?

Run-time Verification

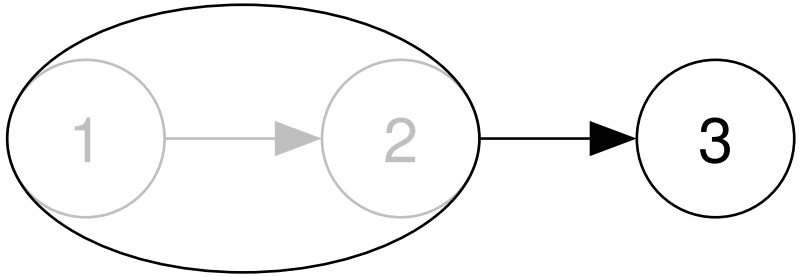


- Concrete values/states
- Full-sized system
- Testing never exhaustive
- Dependent on tests + schedule

May miss errors

Real example scenario

Static Analysis



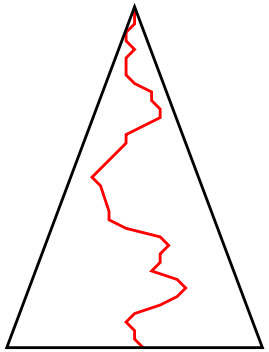
- Abstract values/states
- Smaller system
- Complete exploration possible
- Requires precise pointer analysis

Exhaustive search possible

False warnings

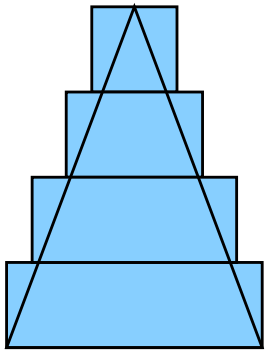
Strengths and weaknesses

Run-time Verification (RV)



- Single event trace
- Depends on schedule
- **Unsound**
- **Precise information**

Static Analysis

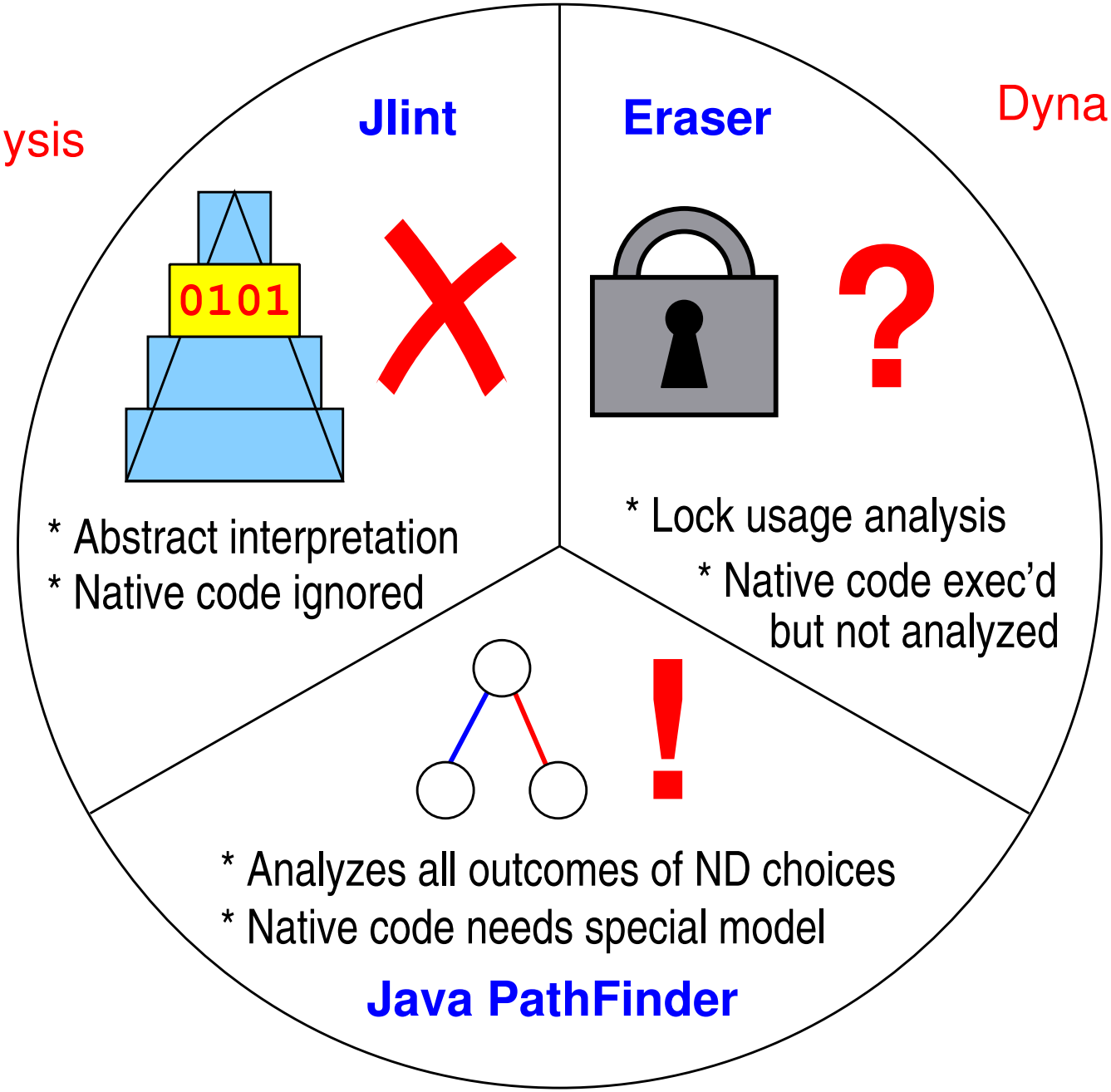


- Over-approximation
- Depends on abstraction
- **Sound**
- **Requires manual tuning**

Complementary technologies

- Tools typically support only one given programming language.

Verification platforms for Java and native code



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Platform mismatch between application and library

Layer	Language	Description
Application	**Java**	**Target of this project**
Java library	**Java**	**High-level functions**
JNI layer	Java	passes library calls to low-level code
JNI impl.	C	C counterpart of JNI
Crypto library	**C**	**Low-level functions**
Device driver	C	(If present) interface to hardware

- Many crypto/security functions are implemented as a C library.
- Existing Java tools only analyze Java code (top three layers).
- How much information from lower layer(s) can we bring to the top?

Example

Java declaration:

```
public final static native void
TPM_NONCE_nonce_set(long jarg1, TPM_NONCE jarg1_, short[] jarg2);
```

C code:

```
SWIGEXPORT void JNICALL
Java_iaik_tc_tss_impl_jni_tsp_TspiWrapperJNI_TSS_1NONCE_1nonce_1set
(JNIEnv *jenv, jclass jcls, jlong jarg1, jobject jarg1_,
 jshortArray jarg2) {
    // other declarations omitted
    if (jarg2 && (*jenv)->GetArrayLength(jenv, jarg2) !=
        TPM_SHA1BASED_NONCE_LEN) {
        SWIG_JavaThrowException(jenv,
                                SWIG_JavaIndexOutOfBoundsException,
                                "incorrect array size");
        return;
    }
...
```

Goal of this project

Layer	Language	Description
Application	**Java**	**Target of this project**
Java library	**Java**	**High-level functions**
JNI layer	Java	passes library calls to low-level code
Crypto library	**C → Java**	**Low-level functions**

Convert native method to Java code:

```
public final static void
TPM_NONCE_nonce_set(long jarg1, TPM_NONCE jarg1_, short[] jarg2) {
    if ((jarg2 != null)
         && (jarg2.length != TPM_SHA1BASED_NONCE_LEN) {
        throw new IndexOutOfBoundsException("incorrect array size");
        return;
    }
}
```

Benefits

- Better integration into the analysis tool.
- Combining properties of multiple implementations.
- Usage of various analysis techniques:
  - static analysis
  - symbolic execution
  - model checking
  - fault injection
- Cross-platform tools do not exist (yet)!

How to bring C code into the Java world?

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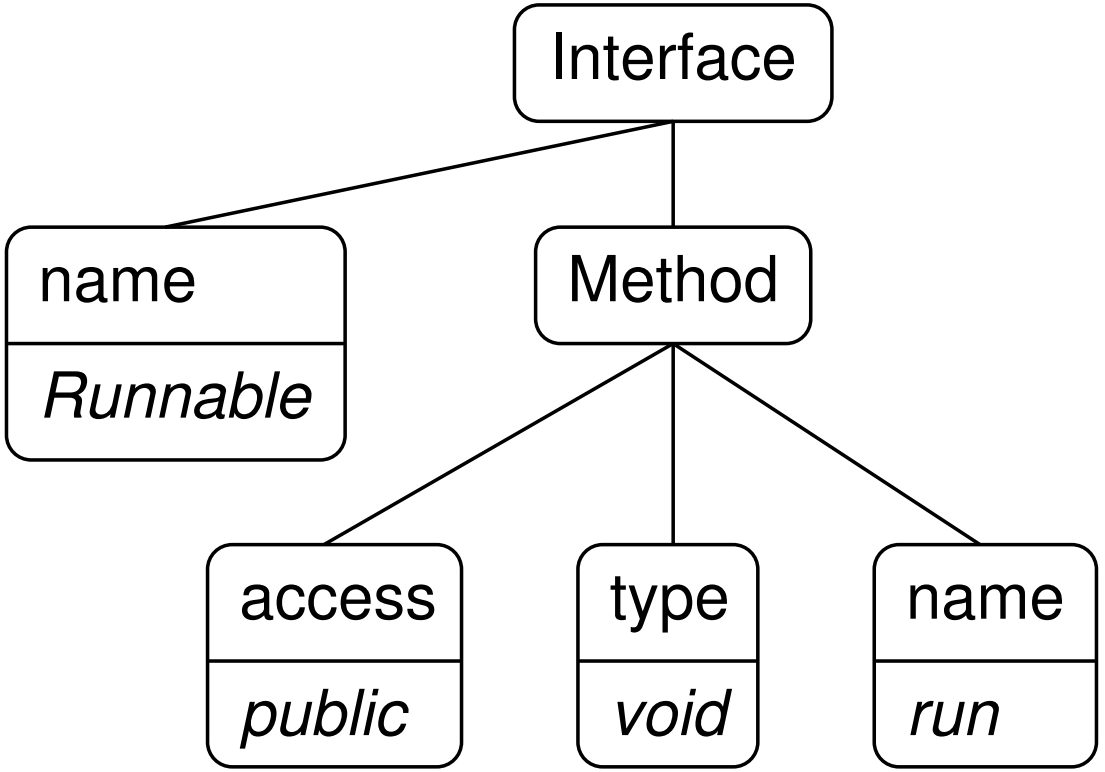
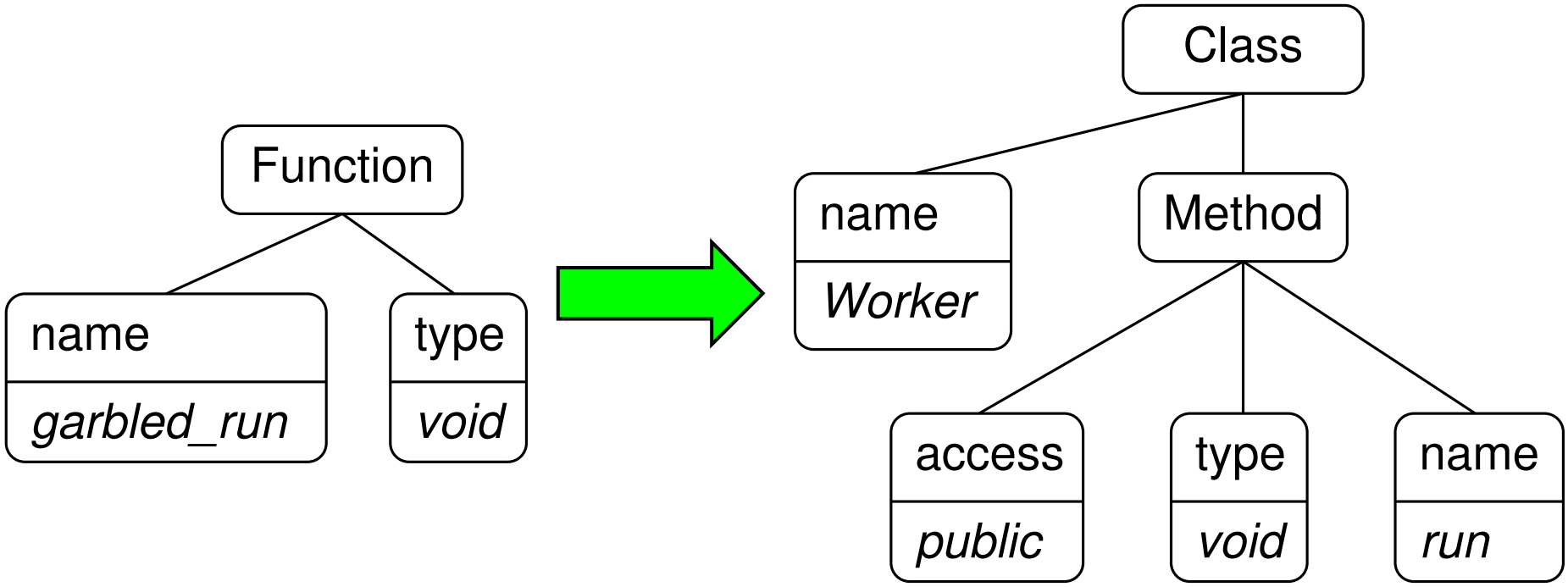
Model-driven architecture



- Domain-specific language models problem data.
- Domain = programming languages.
- Data = Abstract Syntax Tree.

Implementation architecture



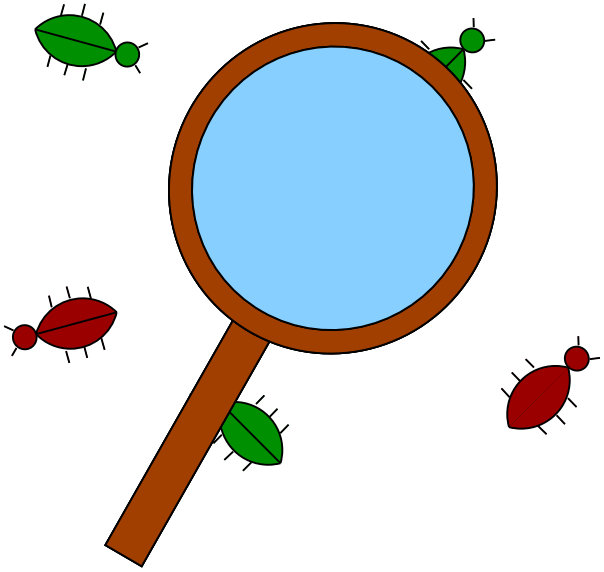
- Create same representation for C and Java code [Gondow, Maruyama].
- Map JNI „name mangling” to Java name.
- Map C code constructs as far as applicable.

Why is a partial code mapping useful?

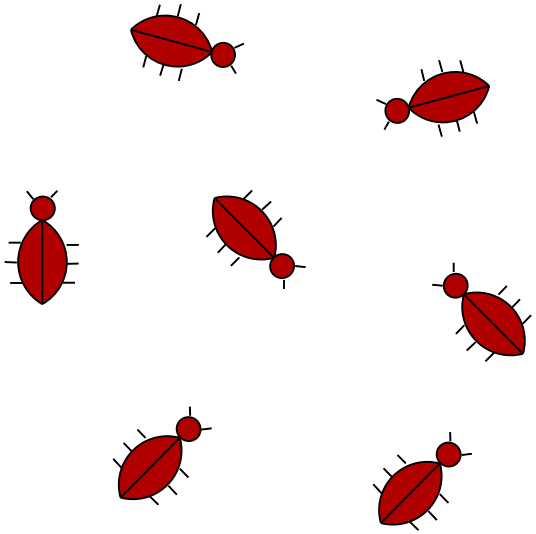
- Analyze Java **Application**.
- Are security APIs used correctly?
  - Under all circumstances: static analysis.
  - Create test cases: symbolic execution.
  - Analyze multi-threading: model checking.
  - Exception handling: fault injection.
- **Implementation** of APIs not relevant.
  - Design by contract: preconditions/postconditions important.
  - Implementation details can be verified by other tools (in C).

Conclusion

Java application



C library

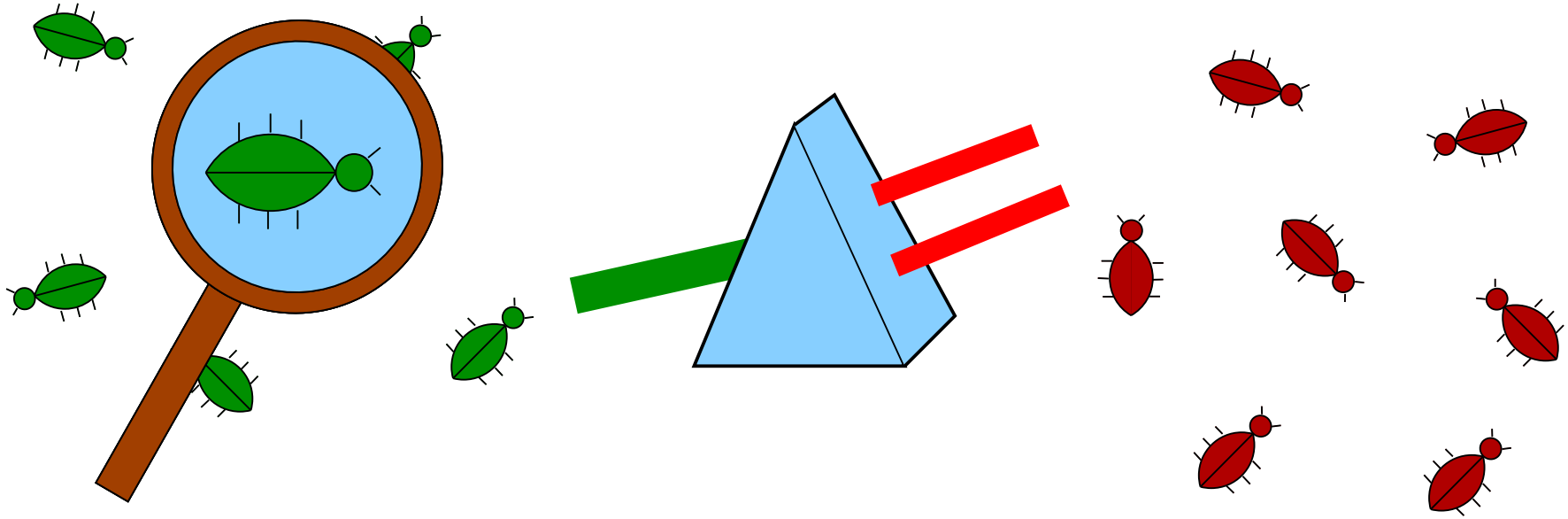


Java analysis tools miss C bugs!

Conclusion

Java application

C library



Make C library usage bugs visible!