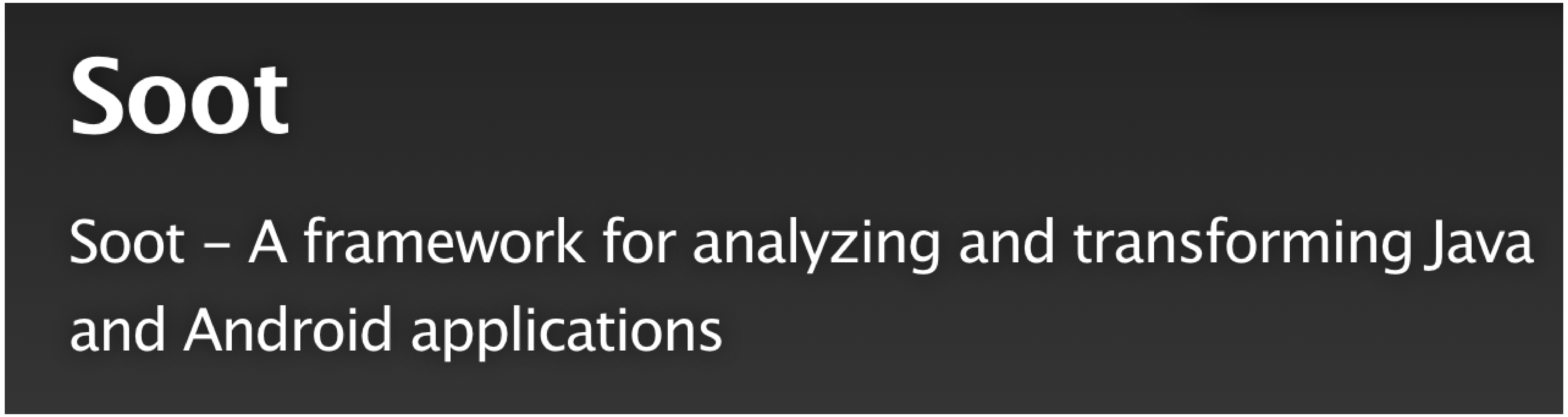
Soot

Java程序分析与变换框架

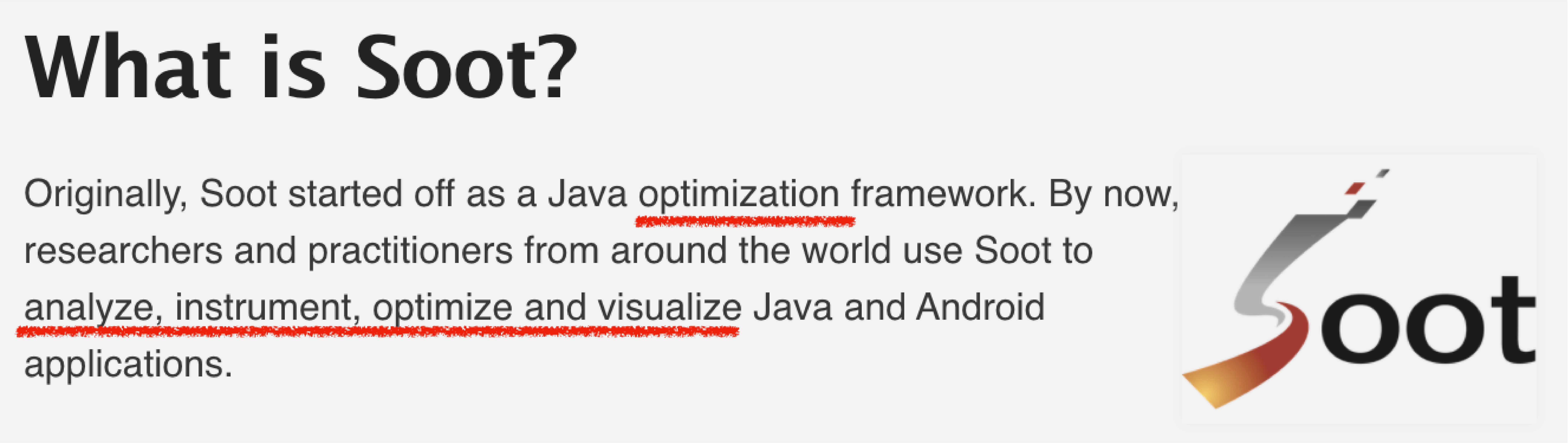
吴宜谦 2021年11月9日

Soot是什么



Soot

Soot – A framework for analyzing and transforming Java and Android applications



What is Soot?

Originally, Soot started off as a Java optimization framework. By now, researchers and practitioners from around the world use Soot to analyze, instrument, optimize and visualize Java and Android applications.

主页： https://soot-oss.github.io/soot/

Soot的开发历程

- Started in 1996-97 with the development of coffi by Clark Verbrugge and some first prototypes of Jimple IR by Clark and Raja Vallée-Rai.
- Originally developed by the **Sable Research Group** of McGill University.
- The first publication on Soot appeared at CASCON 1999.
- The current maintenance is driven by **Eric Bodden**’s Software Engineering Group at Heinz Nixdorf Institute of Paderborn University.
- Currently there are a bunch of extensions to Soot, including **Boomerang**, **FlowDroid** and **Soot-Scala.**

Soot的输入和输出

- Input：Java源码/字节码

- Output：程序分析的结果（如活跃变量）/ 程序的中间表示（如Jimple）

为什么要用Soot?

问题1：分析Java源代码的第一步?

- 直接当成字符串？（别笑，真有[1]）
  - 难以知晓代码结构信息
- 转为**中间表示**（IR）！
  - 保留源码信息（与源代码有明确映射关系）
  - 方便机器理解（更加简单，更加结构化）

[1] Code Completion with Statistical Language Models, Veselin Raychev, Martin Vechev, Eran Yahav, PLDI’14

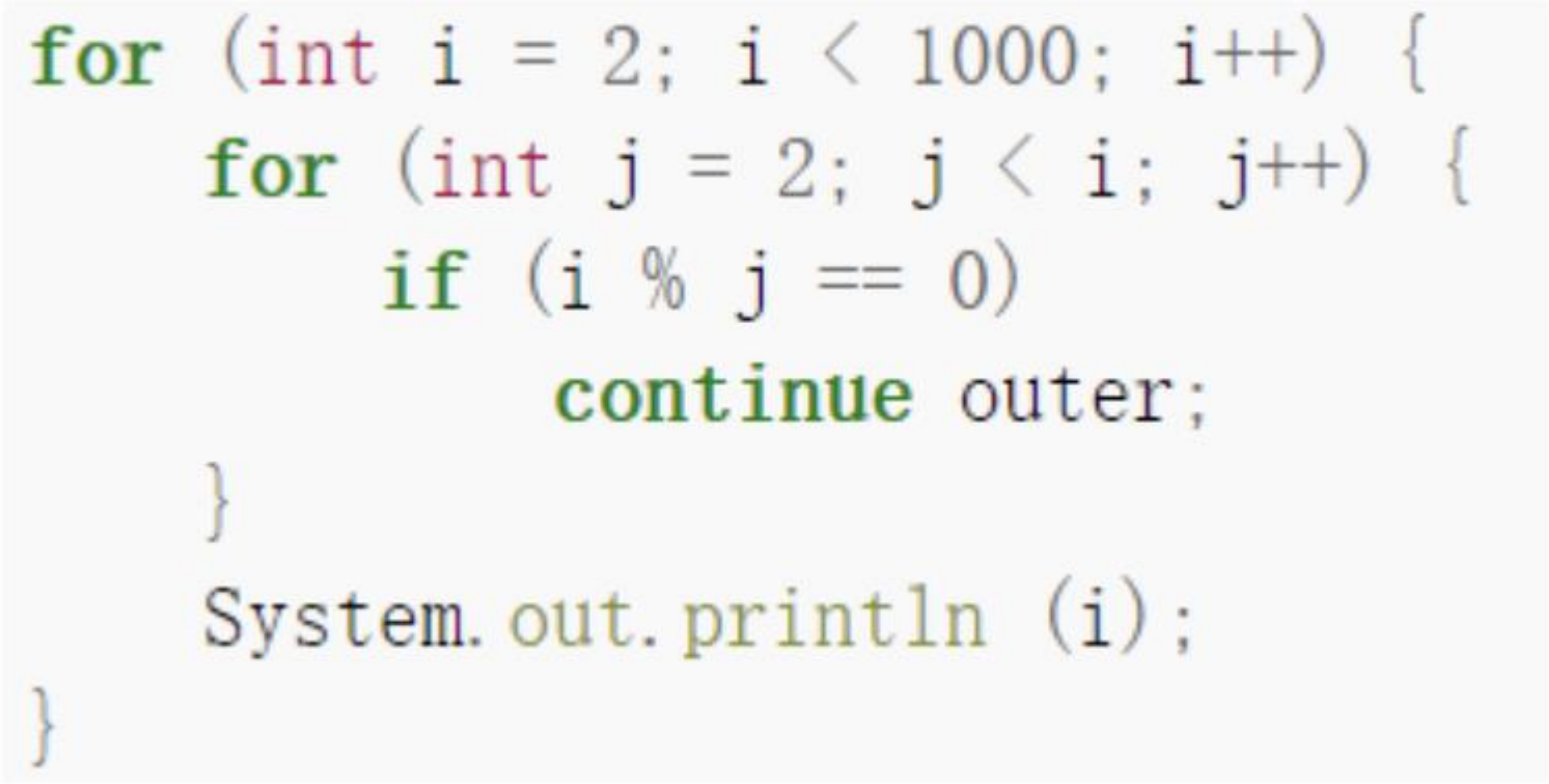
为什么要用Soot?

问题2：使用什么中间表示?

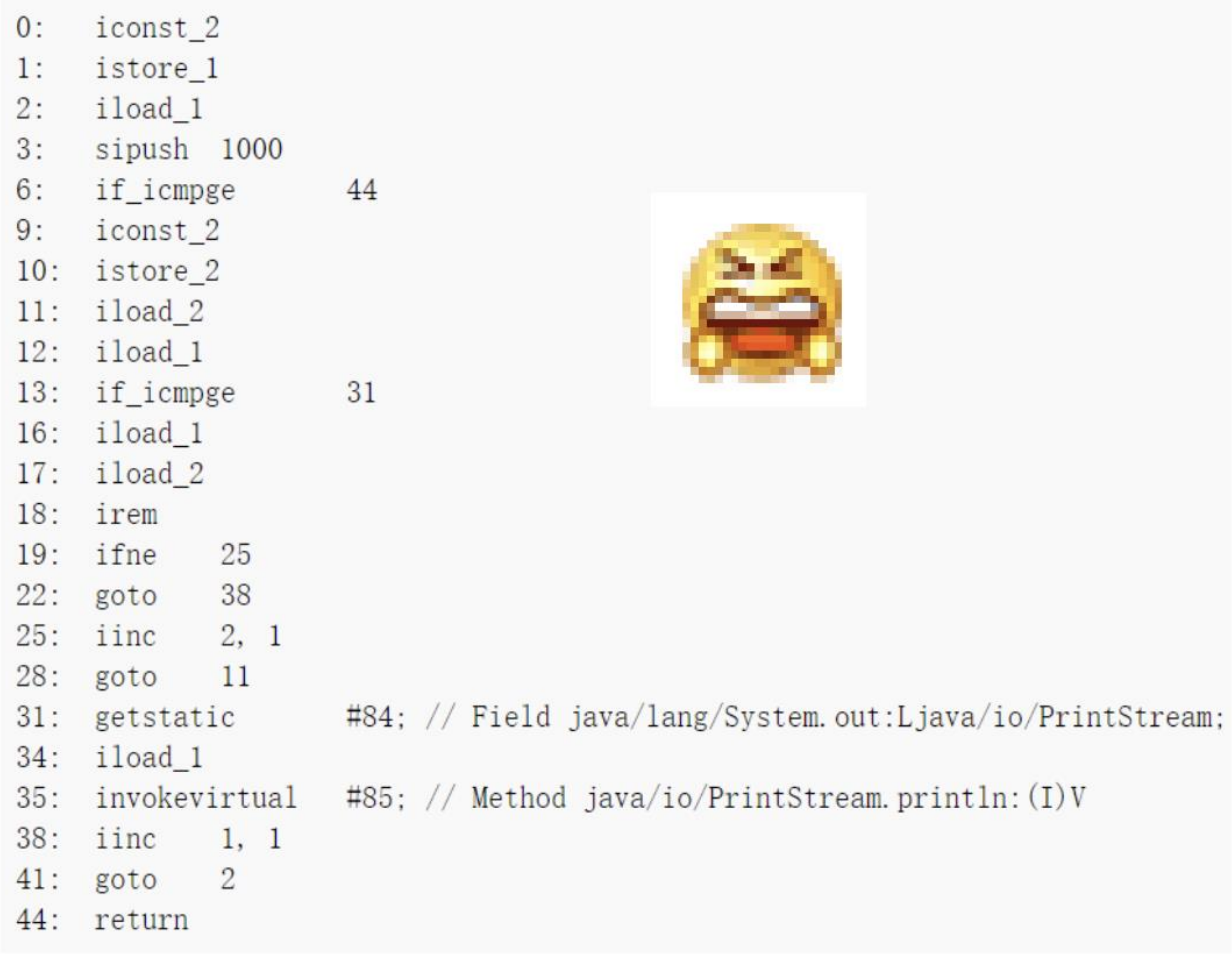
- 直接使用Java bytecode?
  - 😨太贴近机器码（为执行而设计）
  - 😭语句类型～200种（至多有256条指令）
  - 😫基于栈的代码

扩展阅读 https://docs.oracle.com/javase/specs/jvms/se9/html/jvms-6.html#jvms-6.5*/

- 基于栈的代码



```
for (int i = 2; i < 1000; i++) {
    for (int j = 2; j < i; j++) {
        if (i % j == 0)
            continue outer;
    }
    System.out.println (i);
}
```



```
0:   iconst_2
1:   istore_1
2:   iload_1
3:   sipush  1000
6:   if_icmpge       44
9:   iconst_2
10:  istore_2
11:  iload_2
12:  iload_1
13:  if_icmpge       31
16:  iload_1
17:  iload_2
18:  irem
19:  ifne    25
22:  goto    38
25:  iinc    2, 1
28:  goto    11
31:  getstatic       #84; // Field java/lang/System.out:Ljava/io/PrintStream;
34:  iload_1
35:  invokevirtual   #85; // Method java/io/PrintStream.println:(I)V
38:  iinc    1, 1
41:  goto    2
44:  return
```

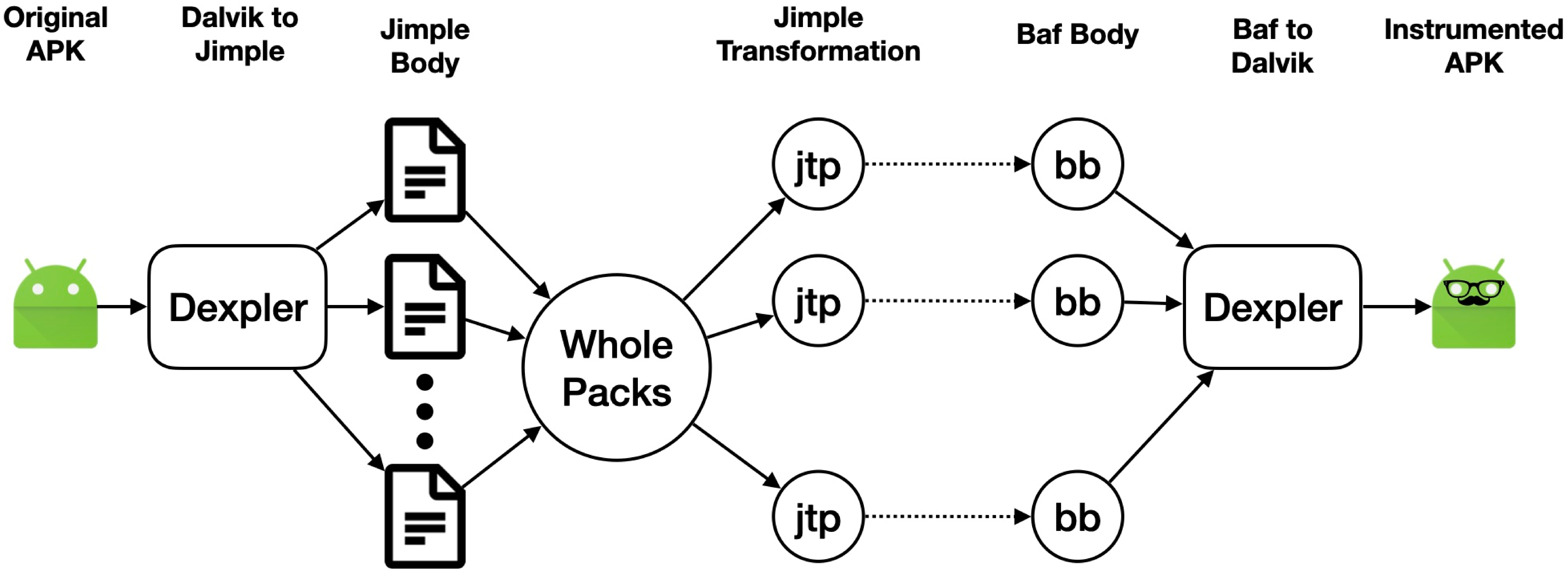
为什么要用Soot?

Soot的中间表示格式

- Soot有四种适合不同程序分析的中间表示：
  - Baf: a streamlined representation of bytecode which is simple to manipulate.
  - **Jimple: a typed 3-address intermediate representation suitable for optimization.**
  - Shimple: an SSA variation of Jimple.
  - Grimp: an aggregated version of Jimple suitable for decompilation and code inspection.

Jimple

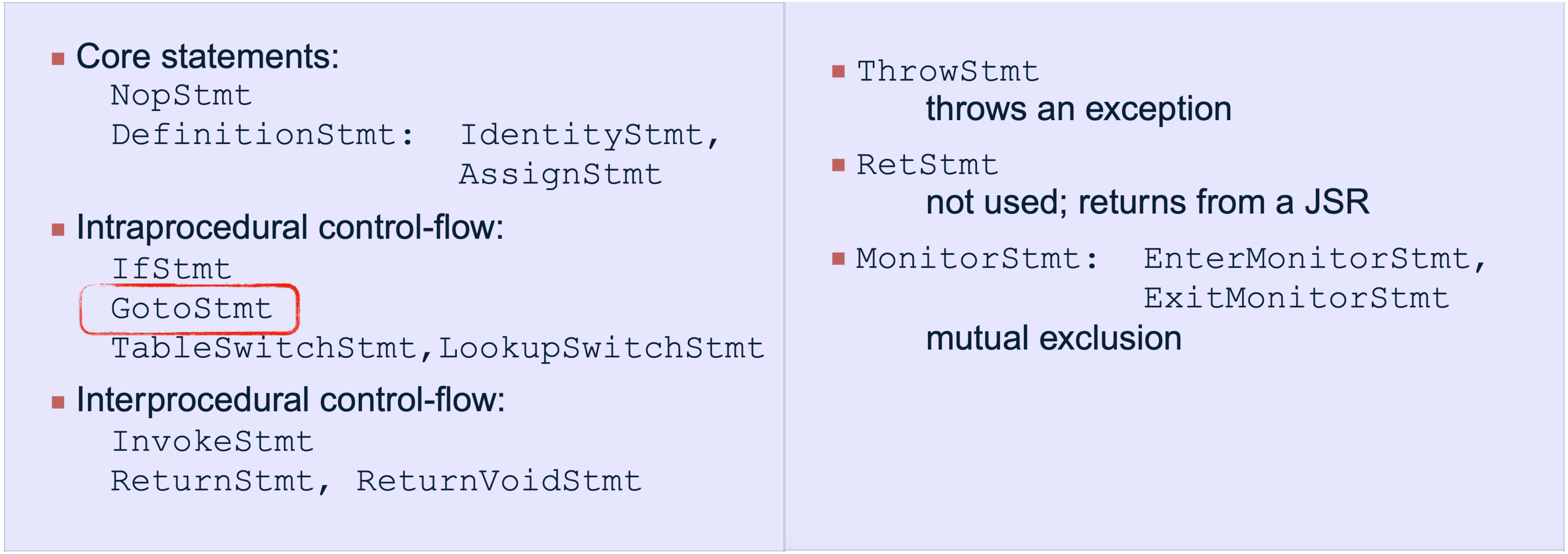
=Java+Simple



Jimple

=Java+Simple

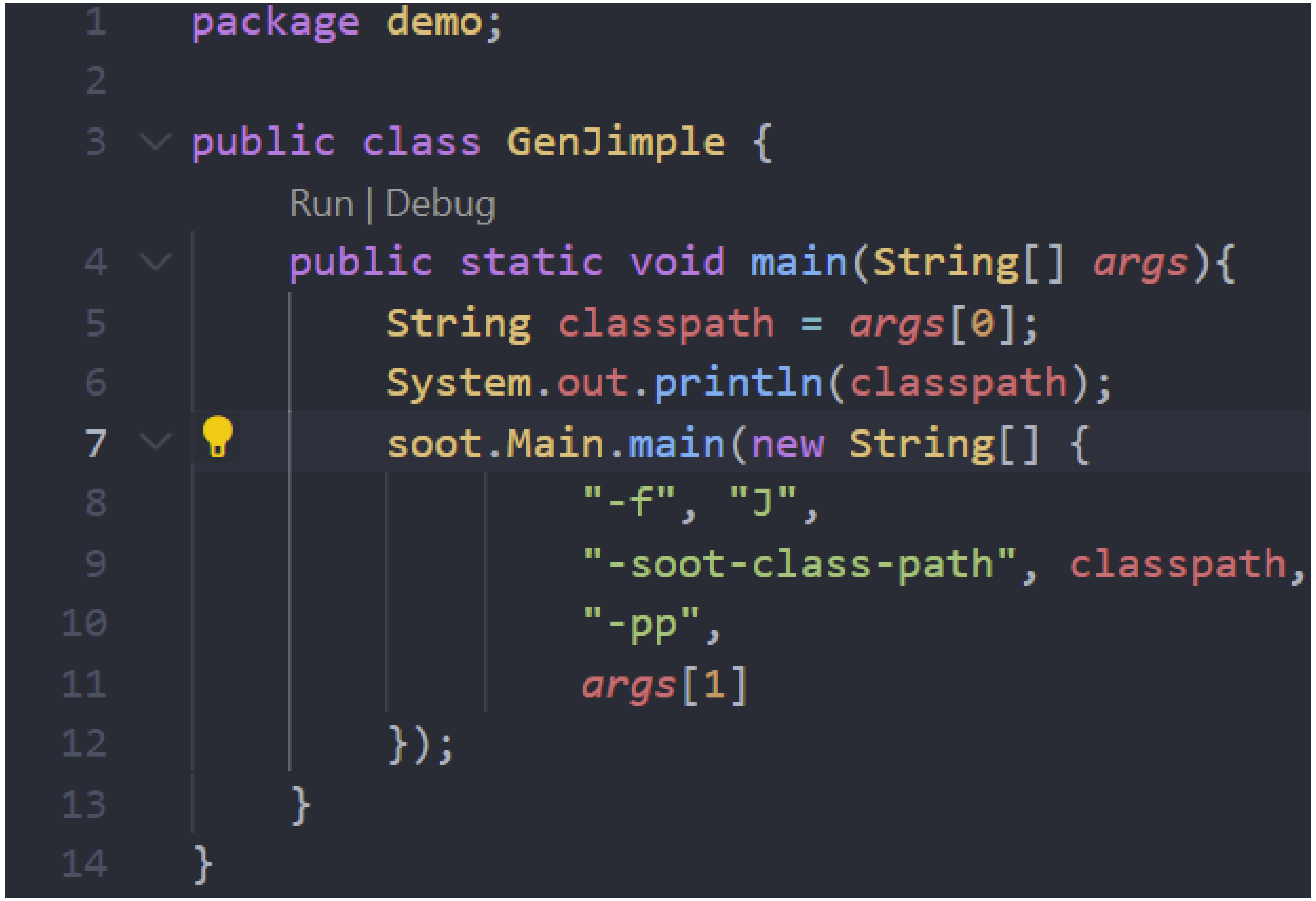
- 😄Jimple只有15种指令



- Core statements:
  `NopStmt`
  `DefinitionStmt:  IdentityStmt,`
  `                  AssignStmt`
- Intraprocedural control-flow:
  `IfStmt`
  `GotoStmt`
  `TableSwitchStmt,LookupSwitchStmt`
- Interprocedural control-flow:
  `InvokeStmt`
  `ReturnStmt, ReturnVoidStmt`
- `ThrowStmt`
  throws an exception
- `RetStmt`
  not used; returns from a JSR
- `MonitorStmt:  EnterMonitorStmt,`
  `              ExitMonitorStmt`
  mutual exclusion

上机实践1

从Java到Jimple



```java
package demo;

public class GenJimple {
    public static void main(String[] args){
        String classpath = args[0];
        System.out.println(classpath);
        soot.Main.main(new String[] {
                "-f", "J",
                "-soot-class-path", classpath,
                "-pp",
                args[1]
        });
    }
}
```

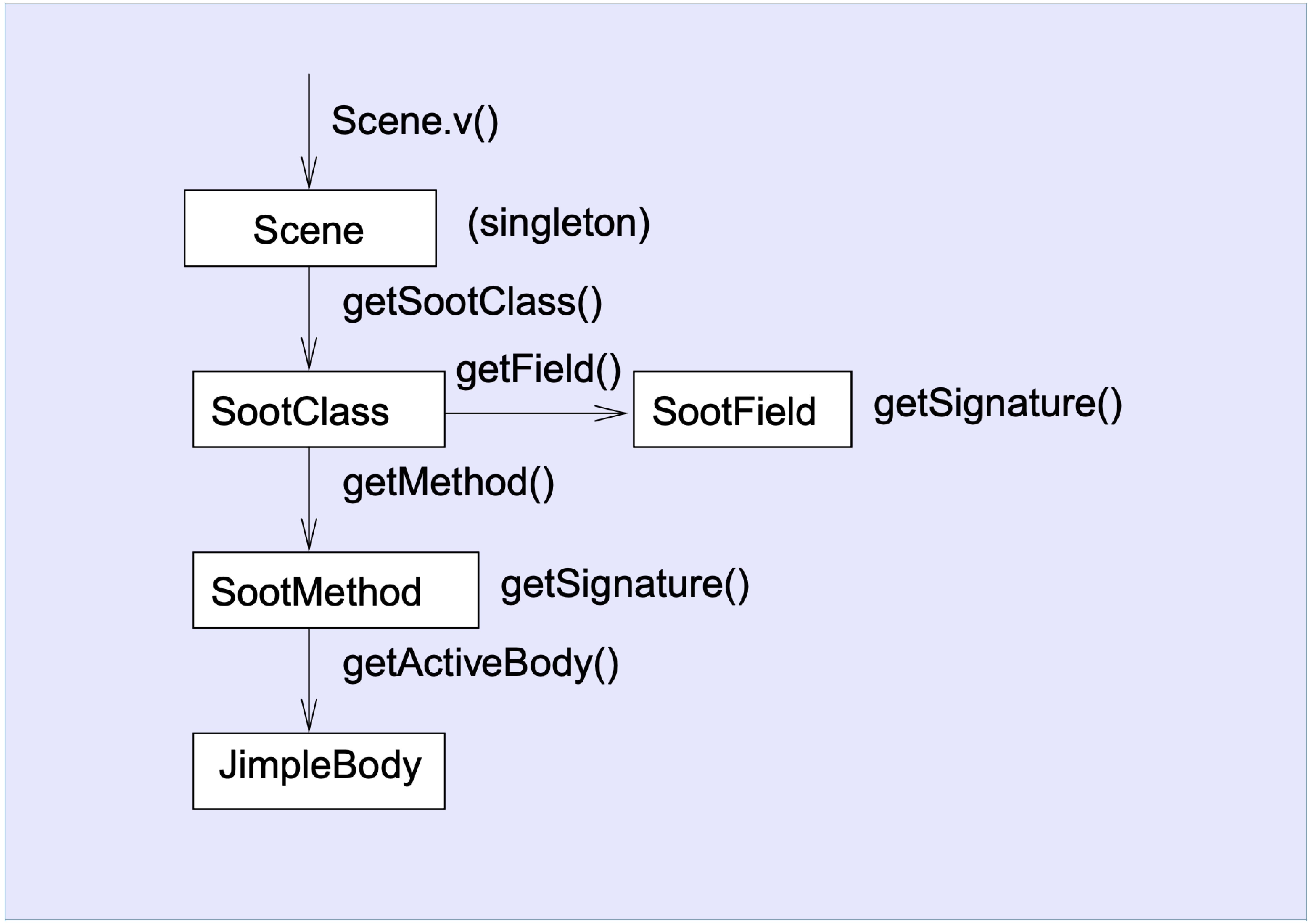
- GenJimple.java
- Soot as a library:

  soot.Main.main(args)

- mvn compile && mvn exec:java "-Dexec.mainClass=demo.GenJimple" "-Dexec.args=./target/classes tests.Main"

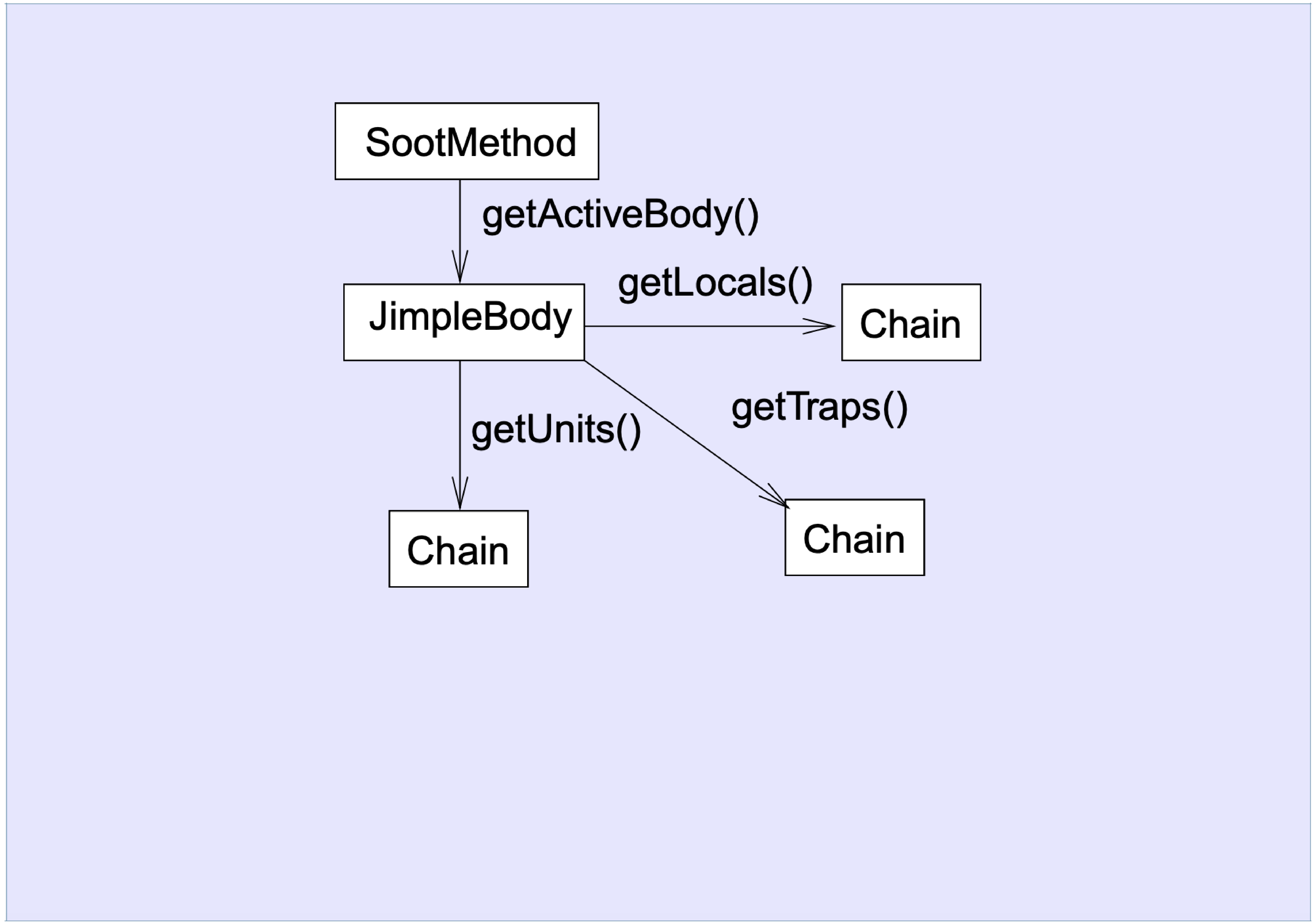
扩展阅读
https://github.com/soot-oss/soot/wiki/Introduction:-Soot-as-a-command-line-tool
https://github.com/soot-oss/soot/wiki/Disassembling-classfiles

Soot的数据结构



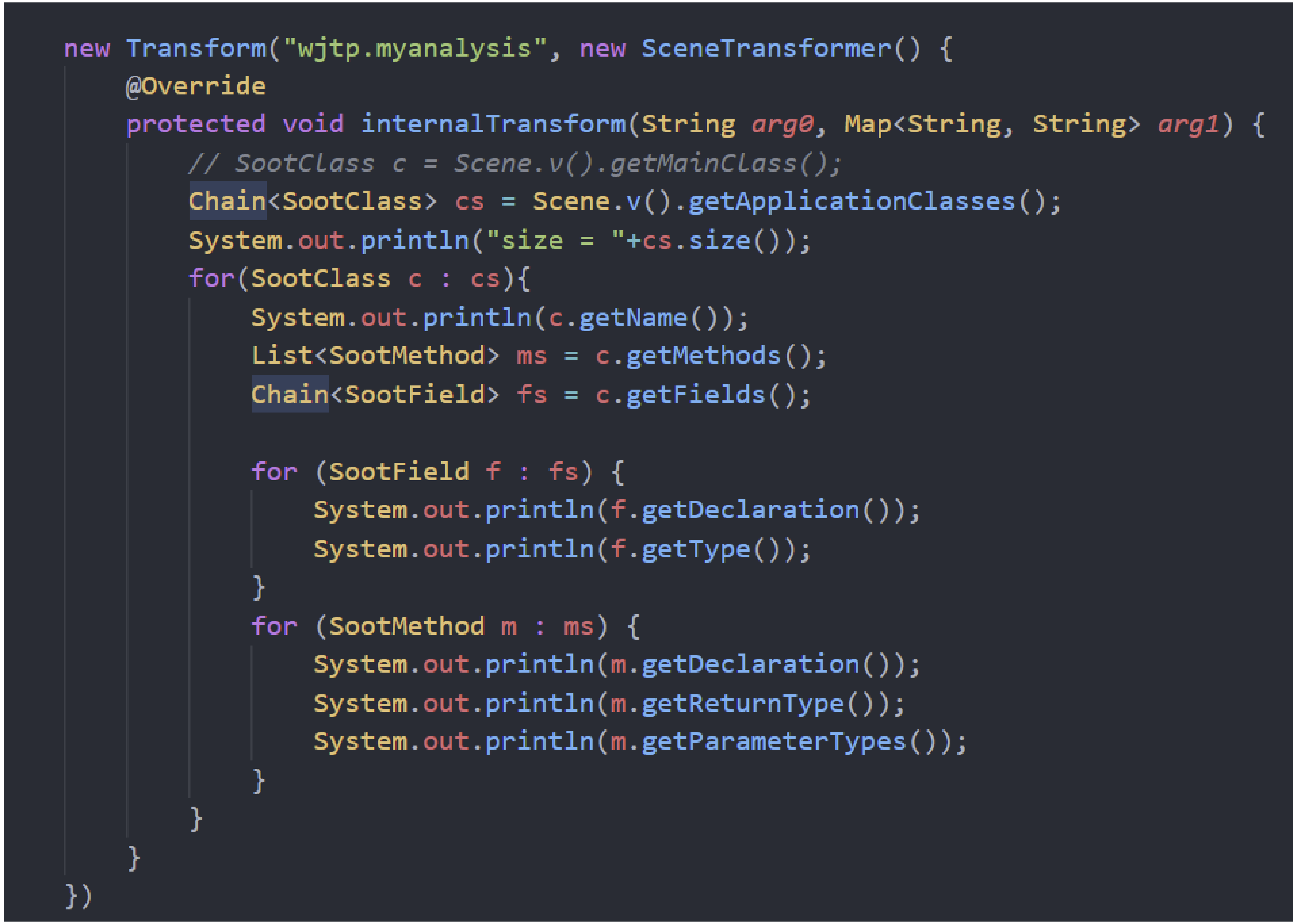
扩展阅读 https://github.com/soot-oss/soot/wiki/Fundamental-Soot-objects

Soot的数据结构


SootMethod
getActiveBody()
JimpleBody
getLocals()
Chain
getUnits()
getTraps()
Chain
Chain

上机实践2

遍历程序结构



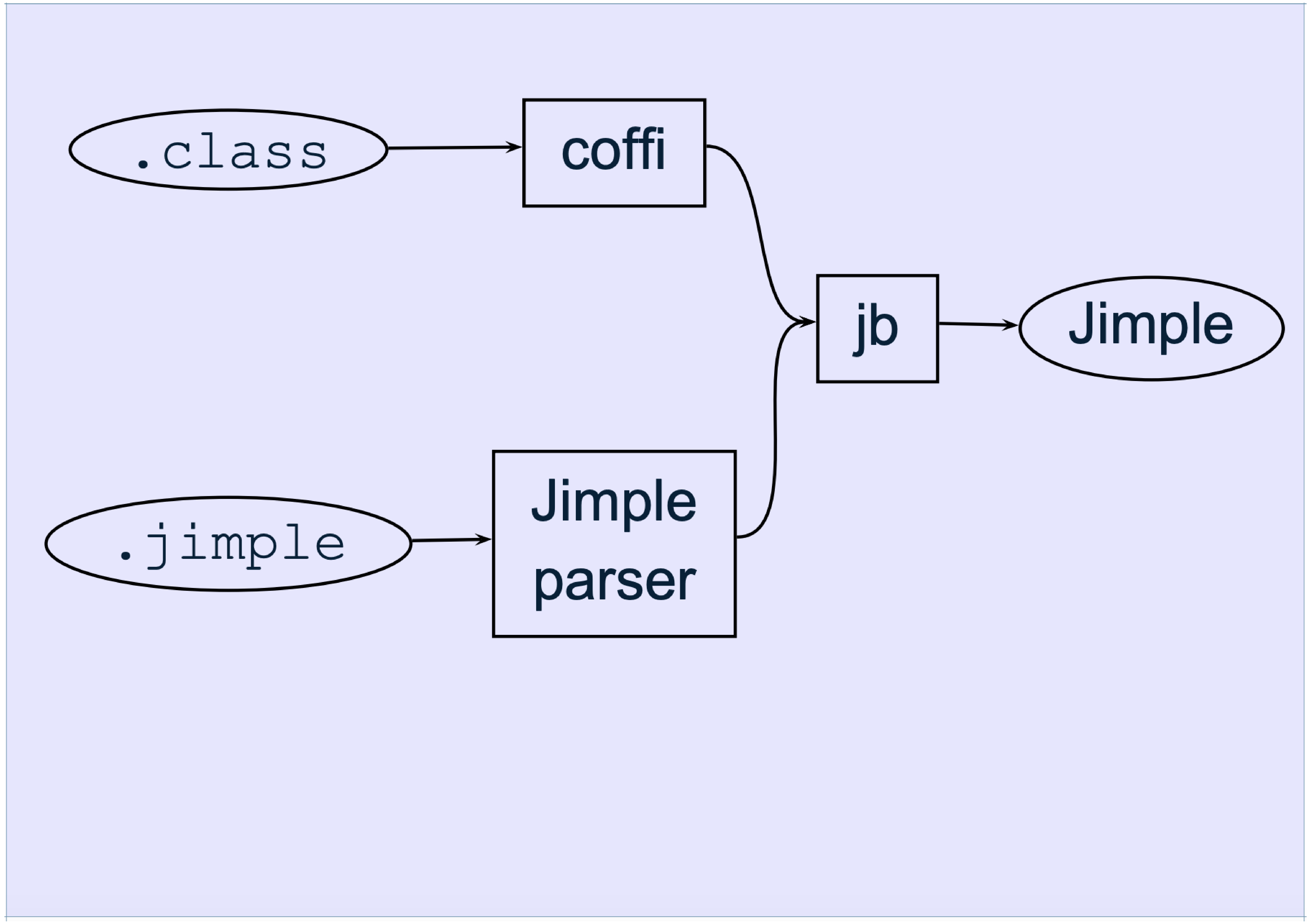
```java
new Transform("wjtp.myanalysis", new SceneTransformer() {
    @Override
    protected void internalTransform(String arg0, Map<String, String> arg1) {
        // SootClass c = Scene.v().getMainClass();
        Chain<SootClass> cs = Scene.v().getApplicationClasses();
        System.out.println("size = "+cs.size());
        for(SootClass c : cs){
            System.out.println(c.getName());
            List<SootMethod> ms = c.getMethods();
            Chain<SootField> fs = c.getFields();

            for (SootField f : fs) {
                System.out.println(f.getDeclaration());
                System.out.println(f.getType());
            }
            for (SootMethod m : ms) {
                System.out.println(m.getDeclaration());
                System.out.println(m.getReturnType());
                System.out.println(m.getParameterTypes());
            }
        }
    }
})
```

- 阅读并运行Traverse.java
- 了解每条语句的效果
- mvn compile && mvn exec:java "-Dexec.mainClass=demo.Traverse" "-Dexec.args=./target/classes/ tests"

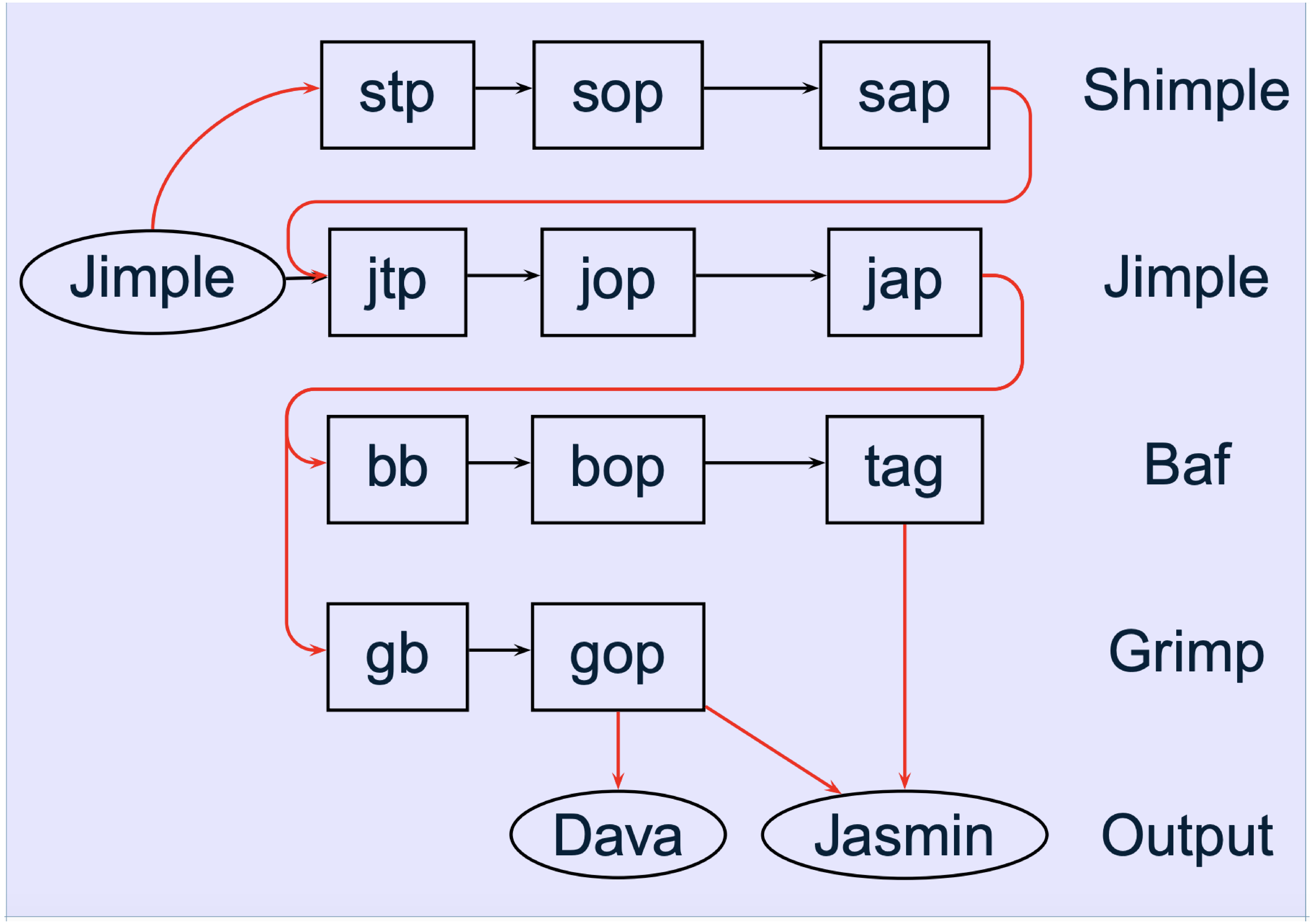
Soot的执行流程

Pack & Phase



Soot的执行流程

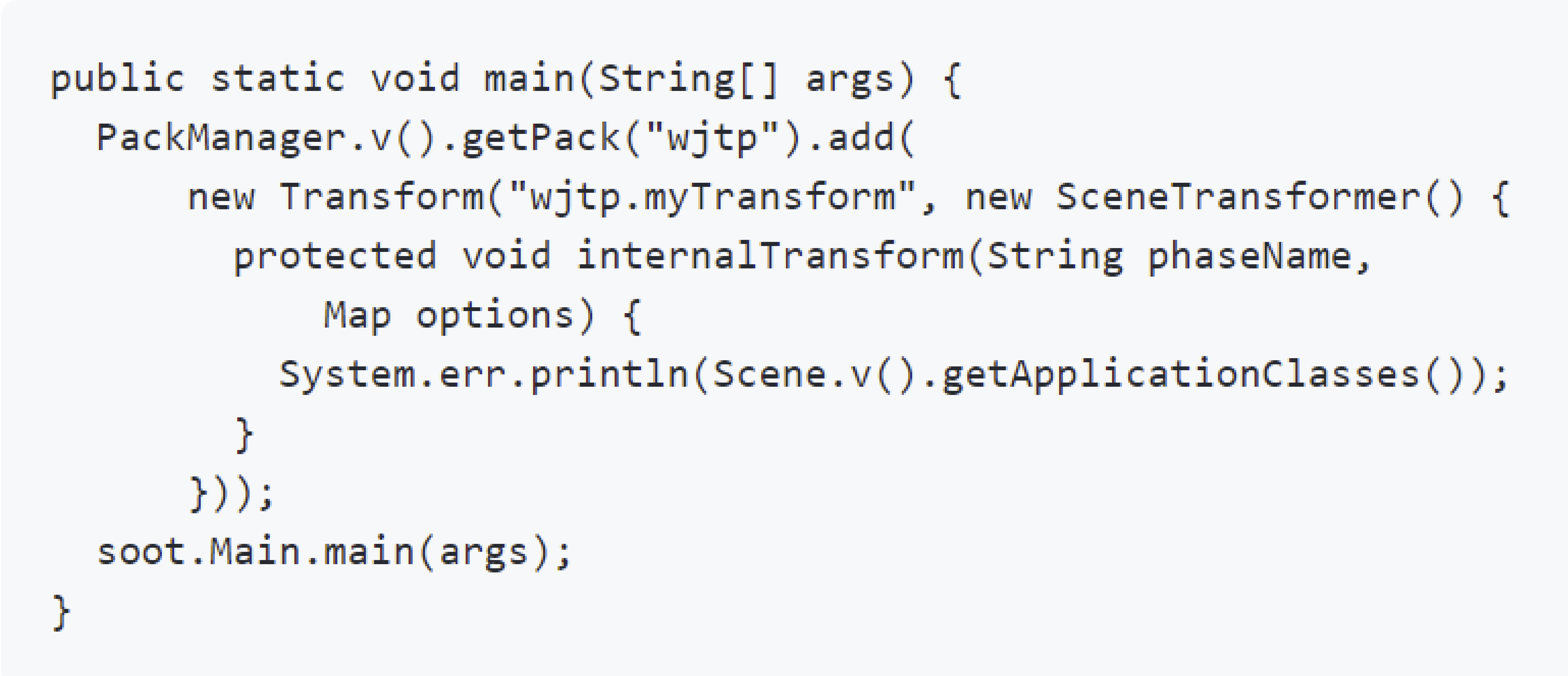
Pack & Phase



Soot的执行流程

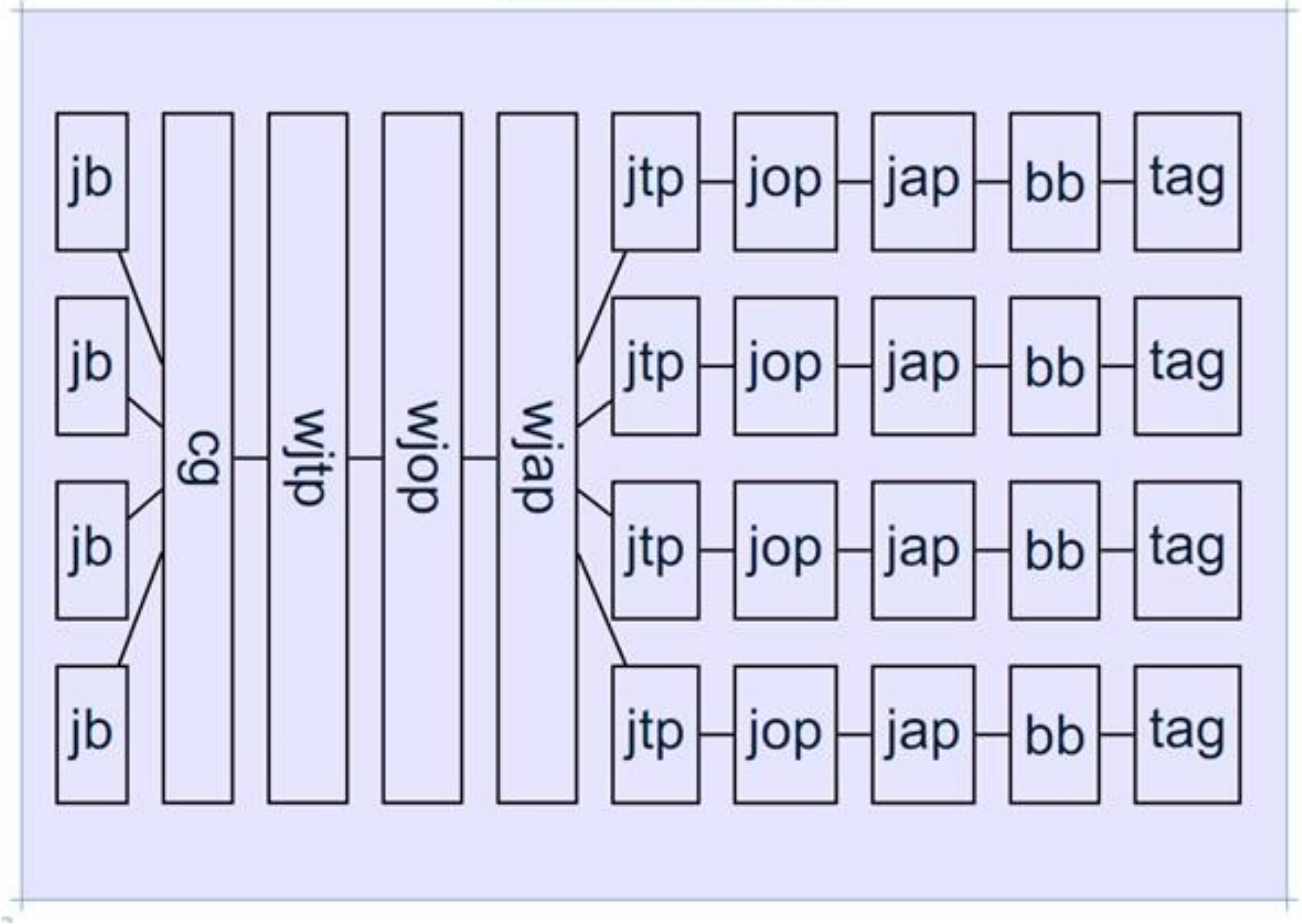
Pack & Phase

- https://github.com/soot-oss/soot/wiki/Packs-and-phases-in-Soot
- Whole-program packs

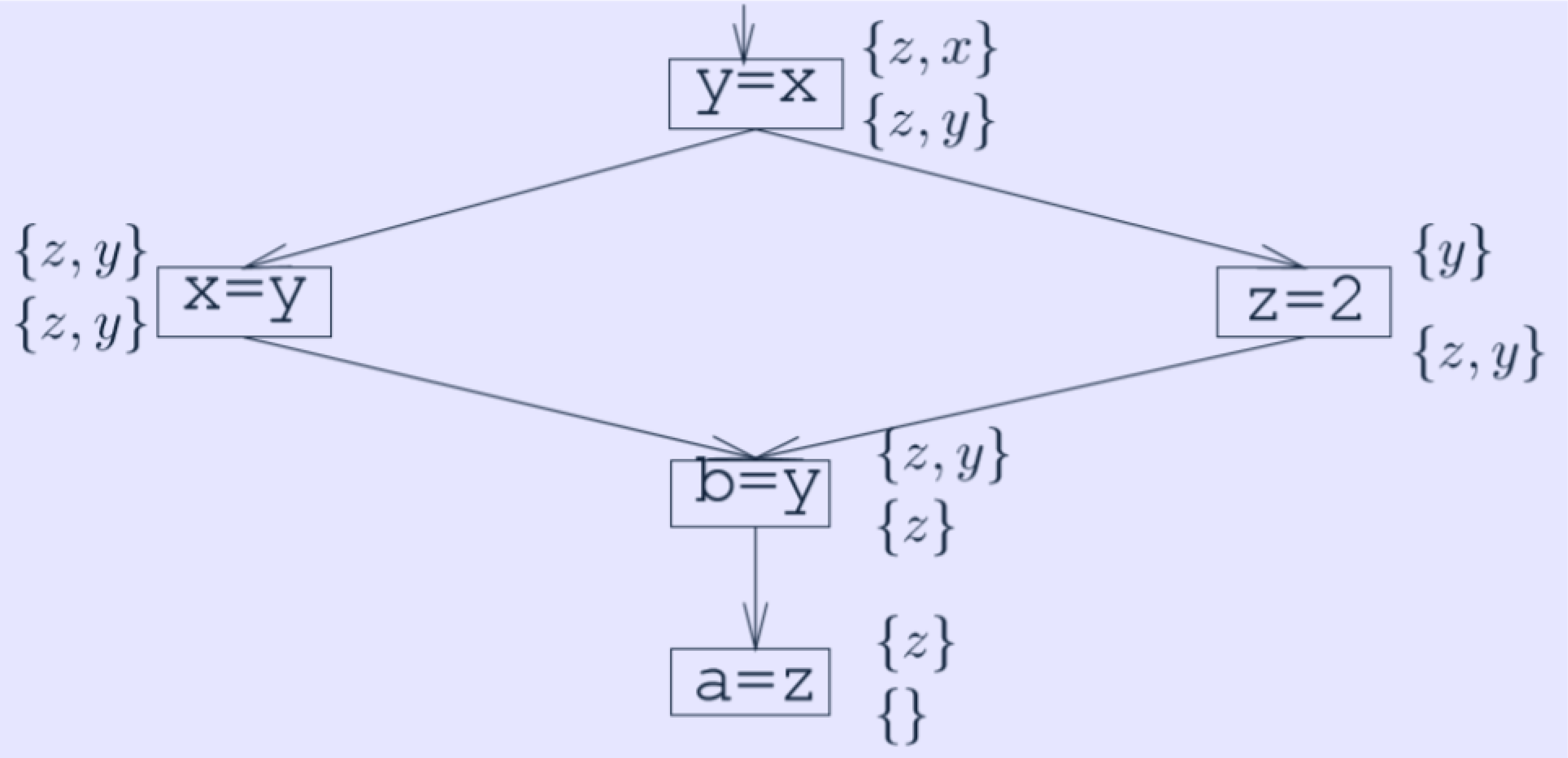


```
public static void main(String[] args) {
  PackManager.v().getPack("wjtp").add(
      new Transform("wjtp.myTransform", new SceneTransformer() {
        protected void internalTransform(String phaseName,
            Map options) {
          System.err.println(Scene.v().getApplicationClasses());
        }
      }));
  soot.Main.main(args);
}
```

Soot phases



数据流分析



- 活跃变量分析
- https://github.com/soot-oss/soot/wiki/Implementing-an-intra-procedural-data-flow-analysis-in-Soot
- https://soot-build.cs.uni-paderborn.de/public/origin/develop/soot/soot-develop/jdoc/soot/toolkits/scalar/AbstractFlowAnalysis.html

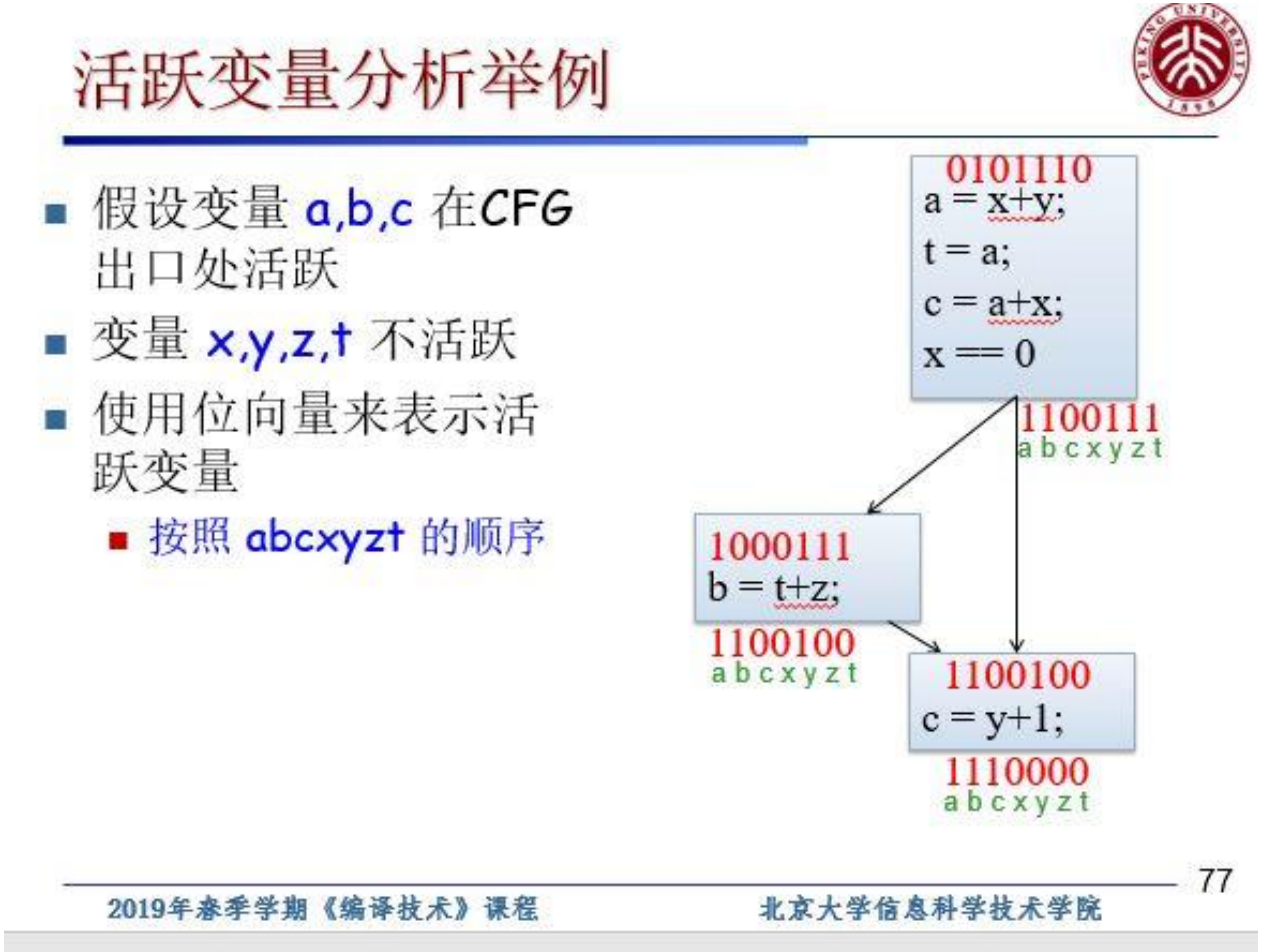
上机练习3

活跃变量分析

- 阅读 GetProgramStructure.java 和 LivenessAnalysis.java
-
  ```
  mvn compile && mvn exec:java "-Dexec.mainClass=demo.GetProgramStructure" "-Dexec.args=./target/classes tests.LiveAnalysis"
  ```

上机练习3

活跃变量分析



活跃变量分析举例

- 假设变量 a,b,c 在CFG出口处活跃
- 变量 x,y,z,t 不活跃
- 使用位向量来表示活跃变量
  - 按照 abcxyzt 的顺序

```
0101110
a = x+y;
t = a;
c = a+x;
x == 0
1100111
abcxyzt

1000111
b = t+z;
1100100
abcxyzt

1100100
c = y+1;
1110000
abcxyzt
```

77

2019年春季学期《编译技术》课程 北京大学信息科学技术学院

参考资料

- A Survivor's Guide to Java Program Analysis with Soot. Arni Einarsson and Janus Dam Nielsen. https://www.brics.dk/SootGuide/
- Analyzing Java Programs with Soot. Bruno Dufour. http://www.iro.umontreal.ca/~dufour/cours/ift6315/docs/soot-tutorial.pdf
- Home - soot-oss/soot Wiki - GitHub. https://github.com/soot-oss/soot/wiki
- noidsirius/SootTutorial. https://github.com/noidsirius/SootTutorial

Q & A