Soot: a framework for analysis and optimization of Java

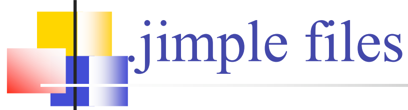
www.sable.mcgill.ca

Java .class files

- Contain fields, methods and attributes
- Fields: instance variables or class variables
- Methods: contain Java bytecode

```
// java source

int cc (int x, int y) {

        int z;

        z = x*y;

        return z; }
```

```
// bytecode(javap –c)
Method int cc (int, int) {
        0 iload 1
        1 iload 2
        2 imul
        3 istore 3
        4 iload 3
        5 ireturn  }
```



jimple files

- An Intermediate Representation

```
// java source

int cc (int x, int y) {

        int z;

        z = x*y;

        return z; }
```

```
// bytecode(javap –c)
Method int cc (int, int) {
        0 iload 1
        1 iload 2
        2 imul
        3 istore 3
        4 iload 3
        5 ireturn  }
```

```
// jimple(java soot.Main -f
jimple)
int cc(int, int)
   {  int i0, i1, i2;
      i0 := @parameter0: int;
      i1 := @parameter1: int;
      i2 = i0 * i1;
      return i2;
   }
```

Intermediate Representations

- Bytecode vs. 3-address code

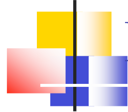
Bytecode:

- Each instruction has implicit effect on stack
- No types for local variables
- > 200 kinds of insts

Typed 3-address code:

- Each stmt acts explicitly on named variables
- Types for each local variable
- Only 15 kinds of stmt

Do analysis on JIMPLE 3-address code IR.



Intermediate Representations

- Source vs. 3-address code

Source

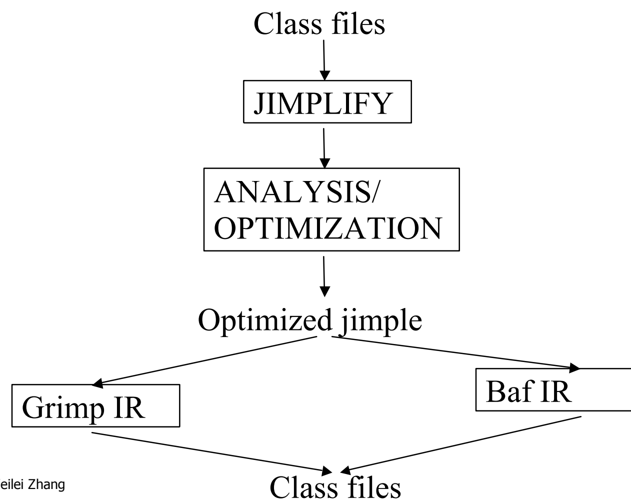
- Irregular structure (somewhat)
- Complex statements and expressions

3-address code:

- More regular structure
- 15 kinds of stmts, simple expressions and statements

Analysis is simpler and more effective on JIMPLE 3-address code than source!

Overview of Soot



Understanding Jimple

- Run soot: java soot.Main –f jimple MyClass

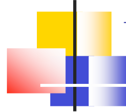
```
public class A {
   main(String[] args) {
      A a = new A();
      a.m();
   }
   public void m() {
   }
}
```

```
public class A extends java.lang.Object
  {
  public void <init>() {
    A r0;
    r0 := @this: A;
    specialinvoke r0.
    <java.lang.Object: void <init>()>();
    return; }
  …
```

Understanding Jimple, cont.

```
public class A {
   main(String[] args) {
      A a = new A();
      a.m();
   }
   public void m() {
   }
}
```

```
…
public void m()
   {
      A r0;
      r0 := @this: A;
      return;
   }
…
```



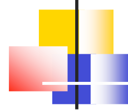
Understanding Jimple, cont.

```
public class A {
   main(String[] args) {
      A a = new A();
      a.m();
   }
   public void m() {
   }
}
```

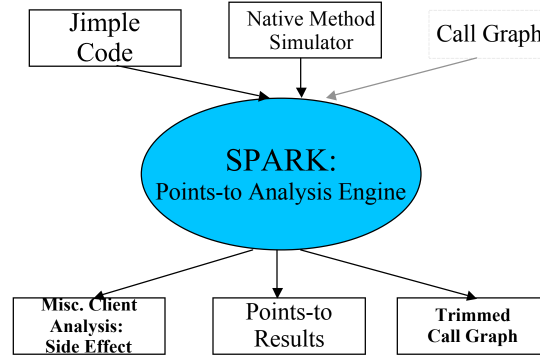
```
…
main(java.lang.String[]) {
      java.lang.String[] r0;
      A $r1, r2;
      r0 := @parameter0: java.lang.String[];
      $r1 = new A;
      specialinvoke $r1.<A: void <init>()>();
      r2 = $r1;
      virtualinvoke r2.<A: void m()>();
      return; }
 }
```

Resources for SOOT

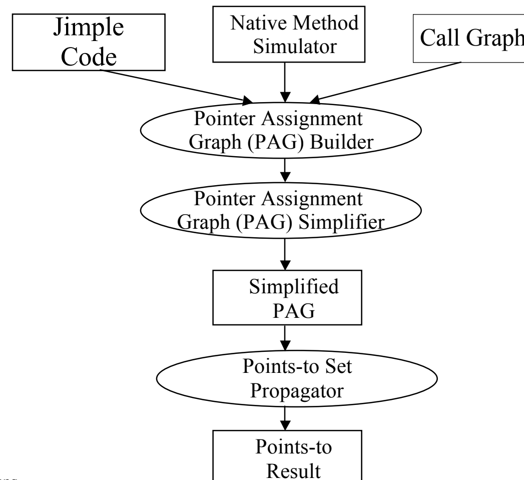
- Master Thesis,"SOOT: A Java Bytecode Optimization Framework",by Raja Vallee-Rai
  http://www.sable.mcgill.ca/publications/thesis/#korMastersThesis
- Tutorial: http://www.sable.mcgill.ca/soot/tutorial/
- paul: /grad/cs515/soot222/soot-2.2.2/tutorial

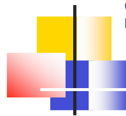


Spark in the Context of SOOT

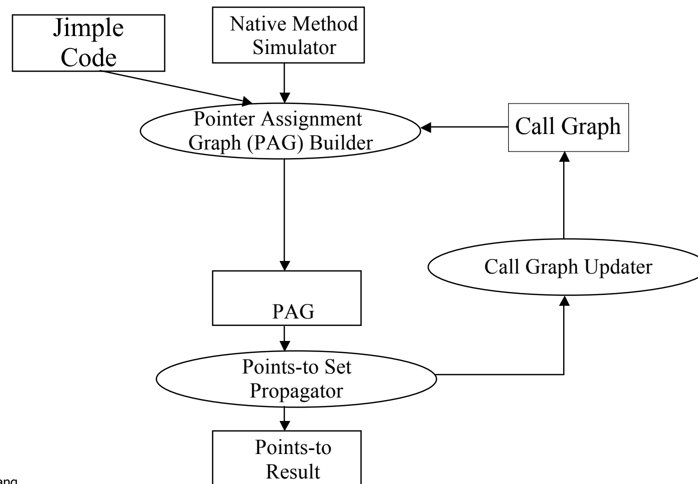


Spark Overview (with Pre-Built Call Graph)





Spark Overview (Call Graph Built On the fly)



Points-to Set Propagator

- Four Statements
  - Allocation (a=new C())
  - Load (a=b.f)
  - Store (b.f=a)
  - Assignment (a=b)
- Type Filter
  - v points-to o =>type(o) is compatible with (subtype of) type(v).
  - Type filter for Assignment and Load statements

Spark Options

- points-to set propagation option(soot.jimple.spark.solver.Propagator)
  - iter: a simple iterative algorithm
  - alias: alias edge based, requires small memory
  - worklist: work list based, fastest
- points-to set implementation
  - hash: java built-in hash set
  - bit: bit vector
  - hybrid: two choices depending on the set size
  - array
  - double: two sets for each points-to set, propagated and not yet propagated (by default two sets are both hybrid)

Command to Run Spark

- To run the program: java –Xmx512m soot.Main --app -p cg.spark on-fly-cg:true -w TargetJavaApplication
  - The Running Time may be long on paul!
  - You can try to set the option for on-fly-cg to false and see what will happen.
- -app : application mode, processing all possible reachable classes
- -w: whole program mode
- More Soot command line options please refer to http://www.sable.mcgill.ca/soot/tutorial/usage/

Resources for SPARK

- Spark Options:
  http://www.sable.mcgill.ca/soot/tutorial/phase/phase.html#SECTION00042000000000000000
- Master Thesis by Ondřej Lhoták
  “Spark: A flexible points-to analysis framework for Java”
  http://plg.uwaterloo.ca/~olhotak/pubs/thesis-olhotak-msc.ps
- Source Code:soot-2.2.2/src/soot/jimple/spark
  SparkTransformer.java