Sub-clones: Considering the Part Rather than the Whole

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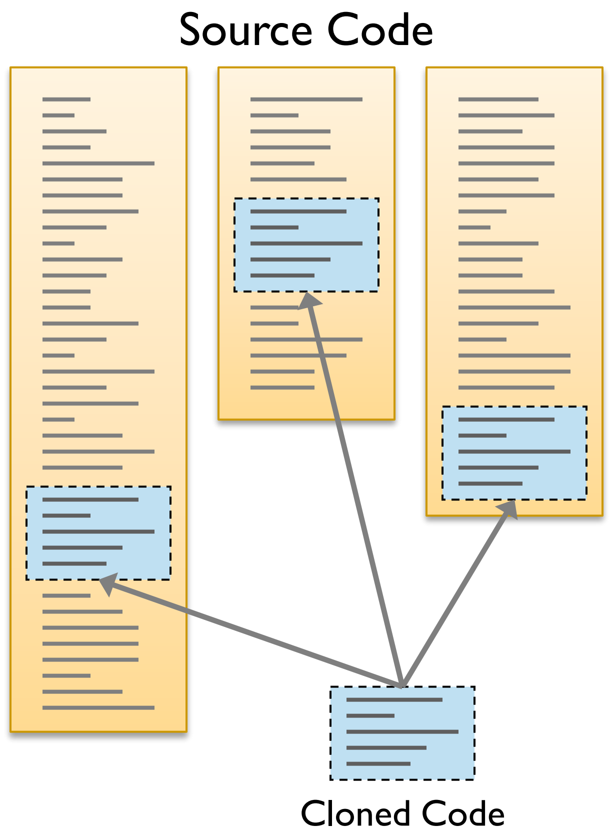
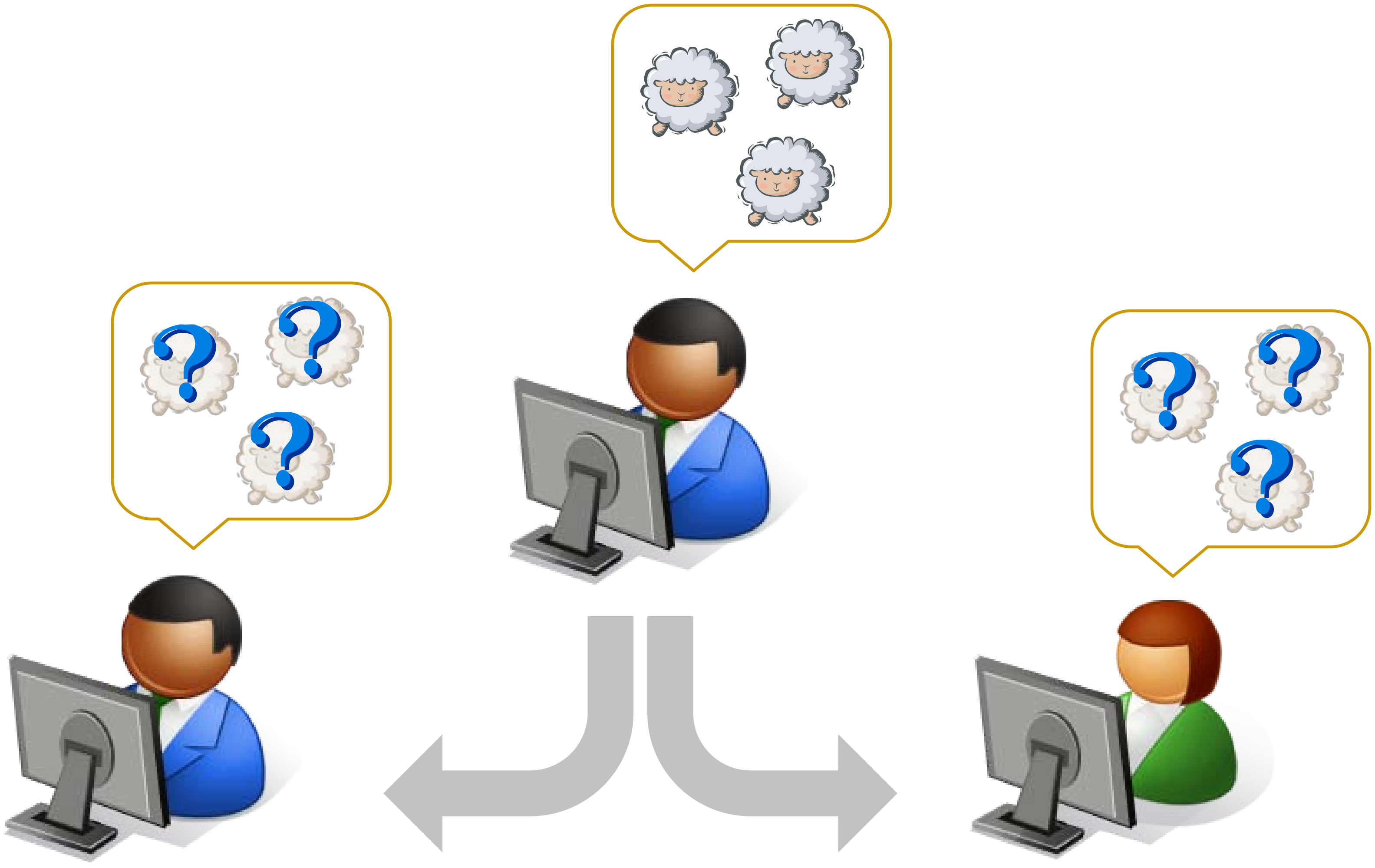
Cloning in Software

- Code Clones:
  - A section of code that is duplicated in multiple locations in a program
- Different granularity levels:
  - Statements, Block, Method, Class, Program
- Clone Group:
  - Clones of the same duplication



Maintaining Clones

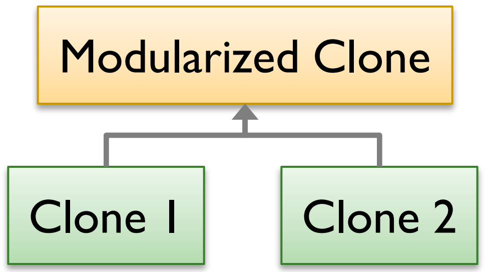


After a period of time

A new programmer

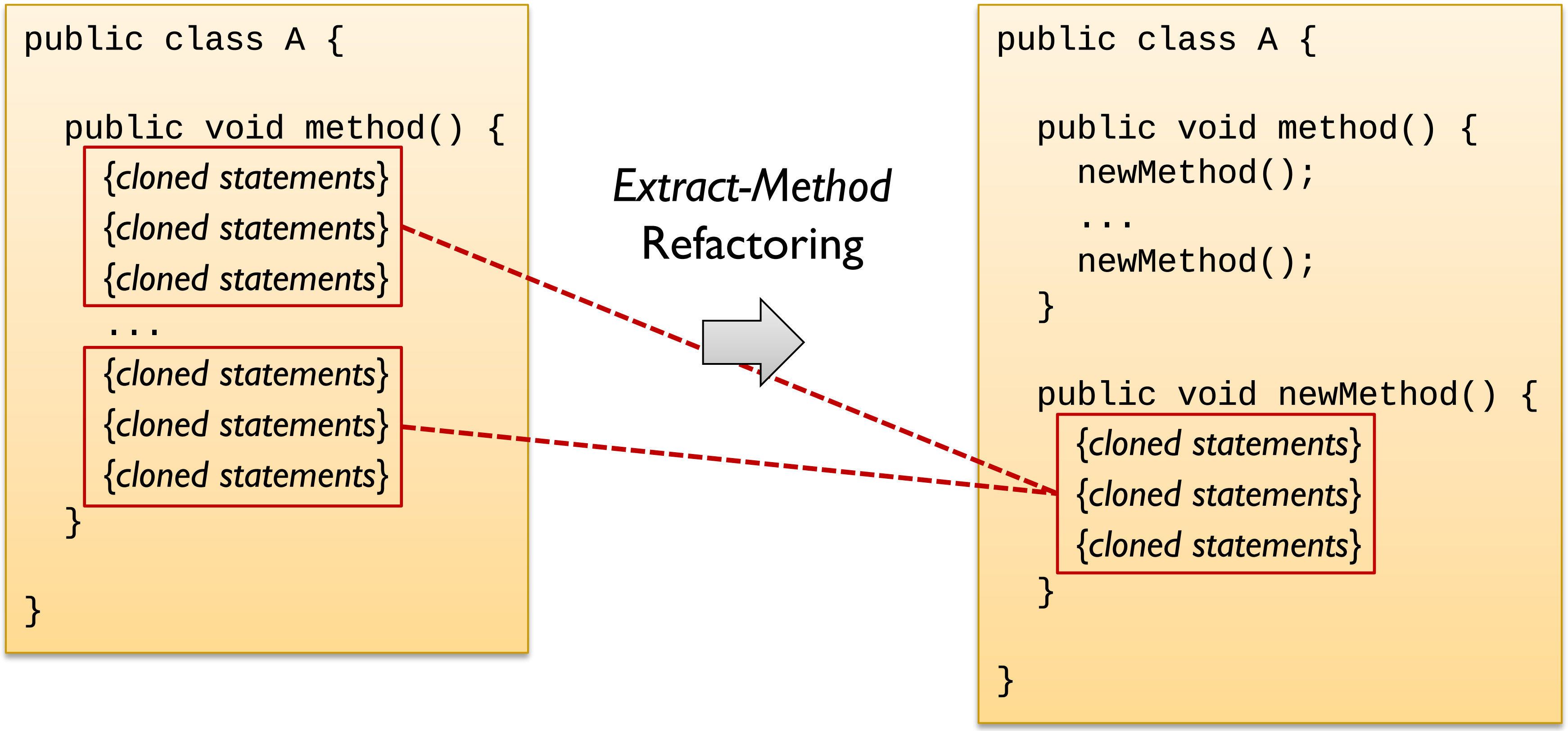
Removing Clones through Refactoring

- Modularizing the code represented by clones through appropriate abstractions may improve code quality
  - Less duplicated code to maintain
  - Ease of future maintenance efforts



- *Refactoring* is one means of improving the quality of code
  - The goal of refactoring is to preserve the external behavior of code while improving its internal structure

Refactoring Clones

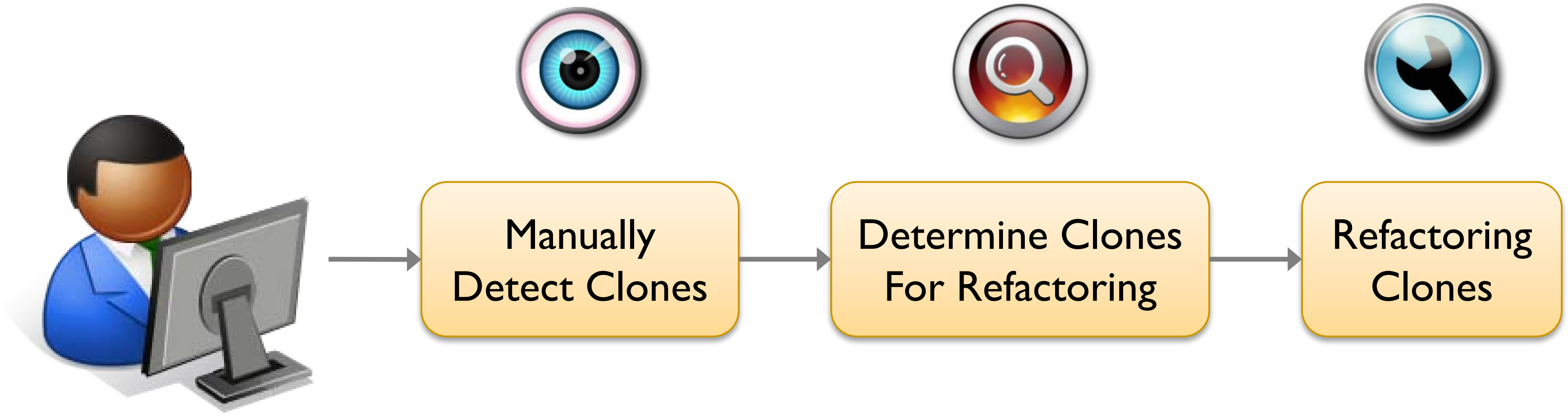


```
public class A {

  public void method() {
    {cloned statements}
    {cloned statements}
    {cloned statements}
    ...
    {cloned statements}
    {cloned statements}
    {cloned statements}
  }

}
```

Extract-Method Refactoring

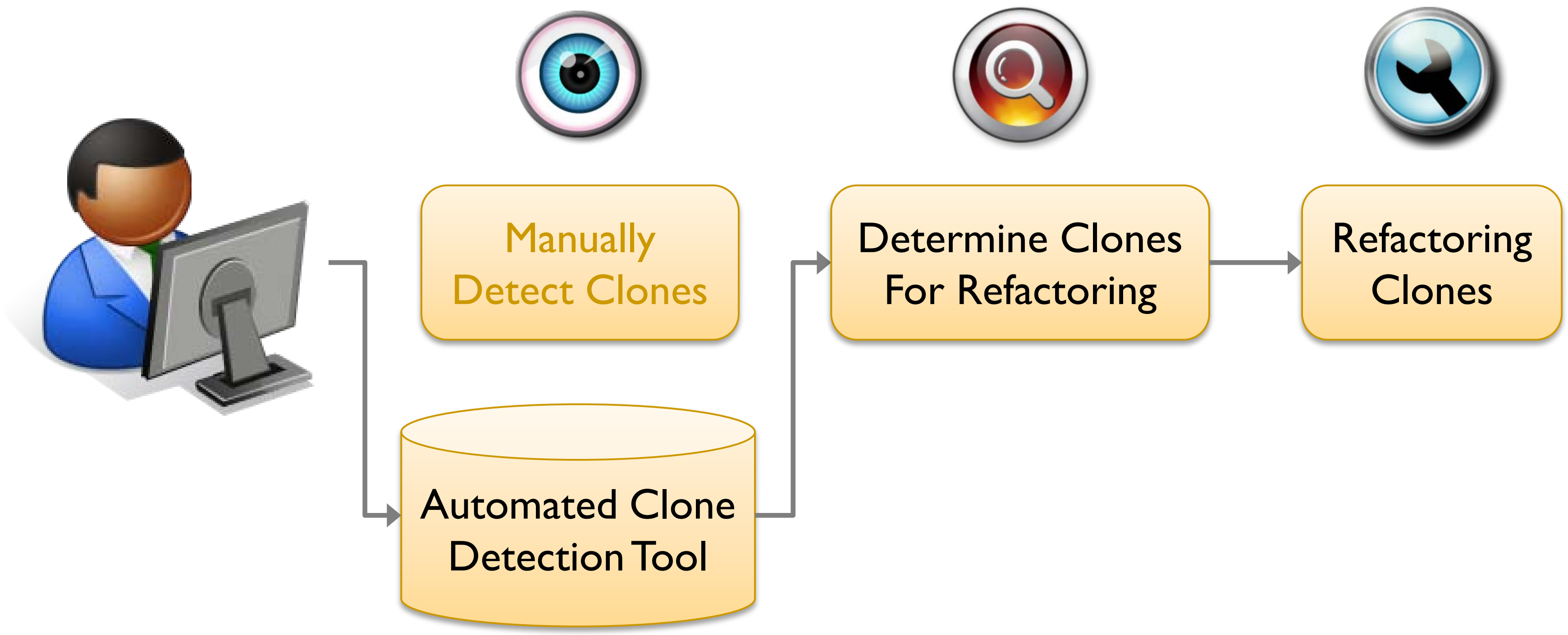
```
public class A {

  public void method() {
    newMethod();
    ...
    newMethod();
  }

  public void newMethod() {
    {cloned statements}
    {cloned statements}
    {cloned statements}
  }

}
```

Clone Refactoring Process



- Changes between two versions
  - First version contains original code
  - Second version contains refactored code

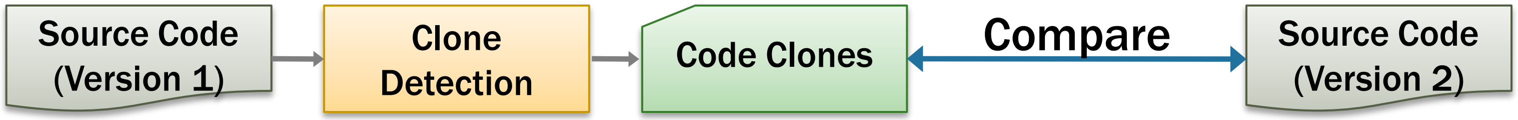
Clone Refactoring Process


Manually Detect Clones
Automated Clone Detection Tool
Determine Clones For Refactoring
Refactoring Clones

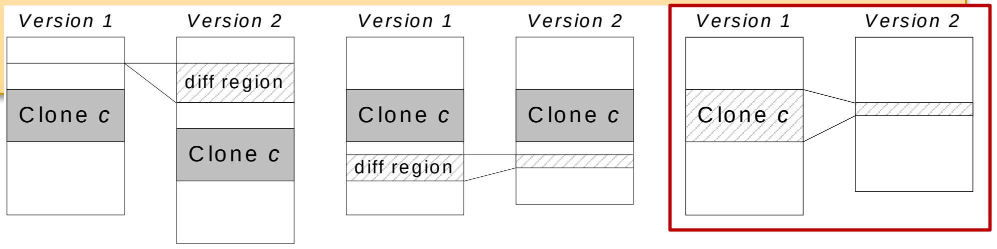
- What are the refactoring characteristics of clones detected by a clone detection tool, if such a tool was used in the clone maintenance process?

Approach: Observing Refactorings

- Observing actual clone-related refactorings in multiple release versions of JBoss (v2.2.0–4.2.3)
  - Used Simian clone detection tool



```
 @@ -2471,13 +2469,7 @@
                 scan_position.current_slot = Page.INVALID_SLOT_NUMBER;

                 // release the scan lock now that we have saved away the row.
-
-                if (scan_position.current_scan_pageno != 0)
-                {
-                   this.getLockingPolicy().unlockScan(
-                      scan_position.current_scan_pageno);
-                   scan_position.current_scan_pageno = 0;
-                }
+                unlockCurrentScan(scan_position);
             }
         }
     }
```



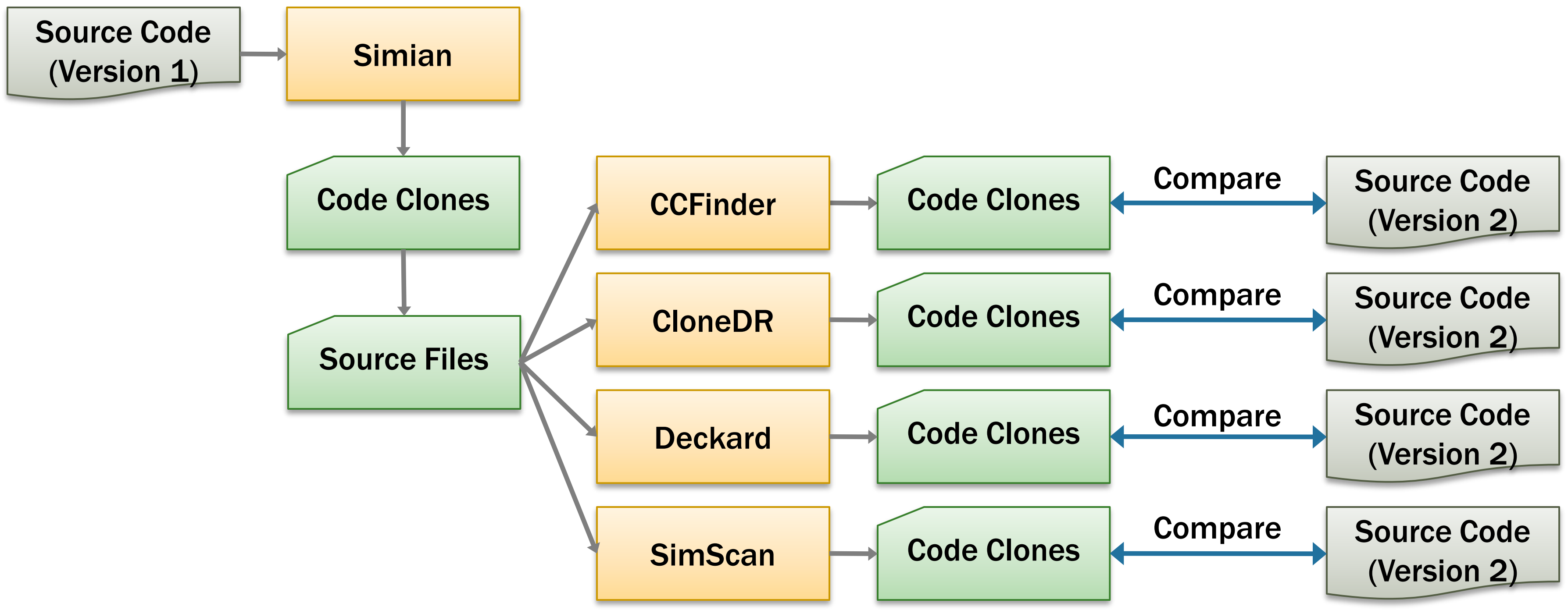
Refactoring of Simian Clones

- Observations
  - 21 *Extract Method*-type Refactorings
  - Range of refactored code not equal to the range reported as a clone

Type	Total
Extract Method	14
Extract Method with *Pull-up Method*	1
Extract Method to utility class	6
Total	21

Observing with Other Tools

- Consider clones reported by other tools
  - CCFinder, CloneDR, Deckard, and SimScan
- Run these tools on source files associated with the 21 *Extract Method*-type refactorings from Simian clones



Evaluation: Tool Coverage

- Coverage of 21 *Extract Method*-type refactorings in JBoss
  - Initially detected by using Simian clones
- Reported clones that exactly covered the refactored code were less than half for all the tools

Tool	Exact Coverage	Larger Coverage
1. CCFinder	4 (19%)	8 (38%)
2. CloneDR	6 (28%)	9 (42%)
3. Deckard	8 (38%)	3 (14%)
4. Simian	2 (9%)	0 (0%)
5. Simscan	6 (28%)	12 (57%)

Refactoring in Clone Ranges

```
1 2   4 5   protected String getValue(String name, String value) {
1 2   4 5     if (value.startsWith("${") && value.endsWith("}")) {
1 2 3 4 5 -     try {
1 2 3 4 5 -       String propertyName = value.substring(2, value.length()-1);
1 2 3 4 5 -       ObjectName propertyServiceON = new ObjectName(“...");
1 2 3 4 5 -       KernelAbstraction kernelAbstraction = KernelAbstractionFactory.getInstance();
1 2 3 4 5 -       String propertyValue = (String)kernelAbstraction.invoke(...);
1 2 3   5 -       log.debug("Replaced ejb-jar.xml element " + name + " with value " + propertyValue);
1 2 3   5 -       return propertyValue;
1 2 3   5 -     } catch (Exception e) {
1 2 3   5 -       log.warn("Unable to look up property service for ejb-jar.xml element " + ...);
1 2 3   5 -     }
          +     String replacement = StringPropertyReplacer.replaceProperties(value);
          +     if (replacement != null)
          +       value = replacement;
1 2     5     }
1 2     5     return value;
1 2     5   }
```

```
   if (edge instanceof MTransition) {
      MTransition tr = (MTransition) edge;
-     FigTrans trFig = new FigTrans(tr);
-     // set source and dest
-     // set any arrowheads, labels, or colors
-     MStateVertex sourceSV = tr.getSource();
-     MStateVertex destSV = tr.getTarget();
-     FigNode sourceFN = (FigNode) lay...
-     FigNode destFN = (FigNode) lay...
-     trFig.setSourcePortFig(sourceFN);
-     trFig.setSourceFigNode(sourceFN);
-     trFig.setDestPortFig(destFN);
-     trFig.setDestFigNode(destFN);
+     FigTrans trFig = new FigTrans(tr, lay);
      return trFig;
   }
```

- Refactoring performed on only part of the reported clone range
  - Sub-clone refactoring

Evaluation: Focus on Deckard

- Deckard selected due to tree-based tool performance
  - JBoss re-evaluated
  - Additional artifacts: ArgoUML (v0.10.1–0.26) and Apache Derby (v10.1.1.0–10.5.3.0)

Property		JBoss	ArgoUML	Derby
Refactoring Coverage	Exact coverage	19	17	12
	Sub-clone coverage	14	9	15
Coverage Levels	Same level	4	4	6
	1 level above	9	2	8
	> 1 level above	1	3	1
Clone Differences	Refactorable	7	4	8
	Not Refactorable	7	5	7

Evaluation: Focus on Deckard

- Reported clone range mainly the same level or one syntactic level above the actual refactored code
  - Possibly to keep some logic in the original location

Property		JBoss	ArgoUML	Derby
Refactoring Coverage	Exact coverage	19	17	12
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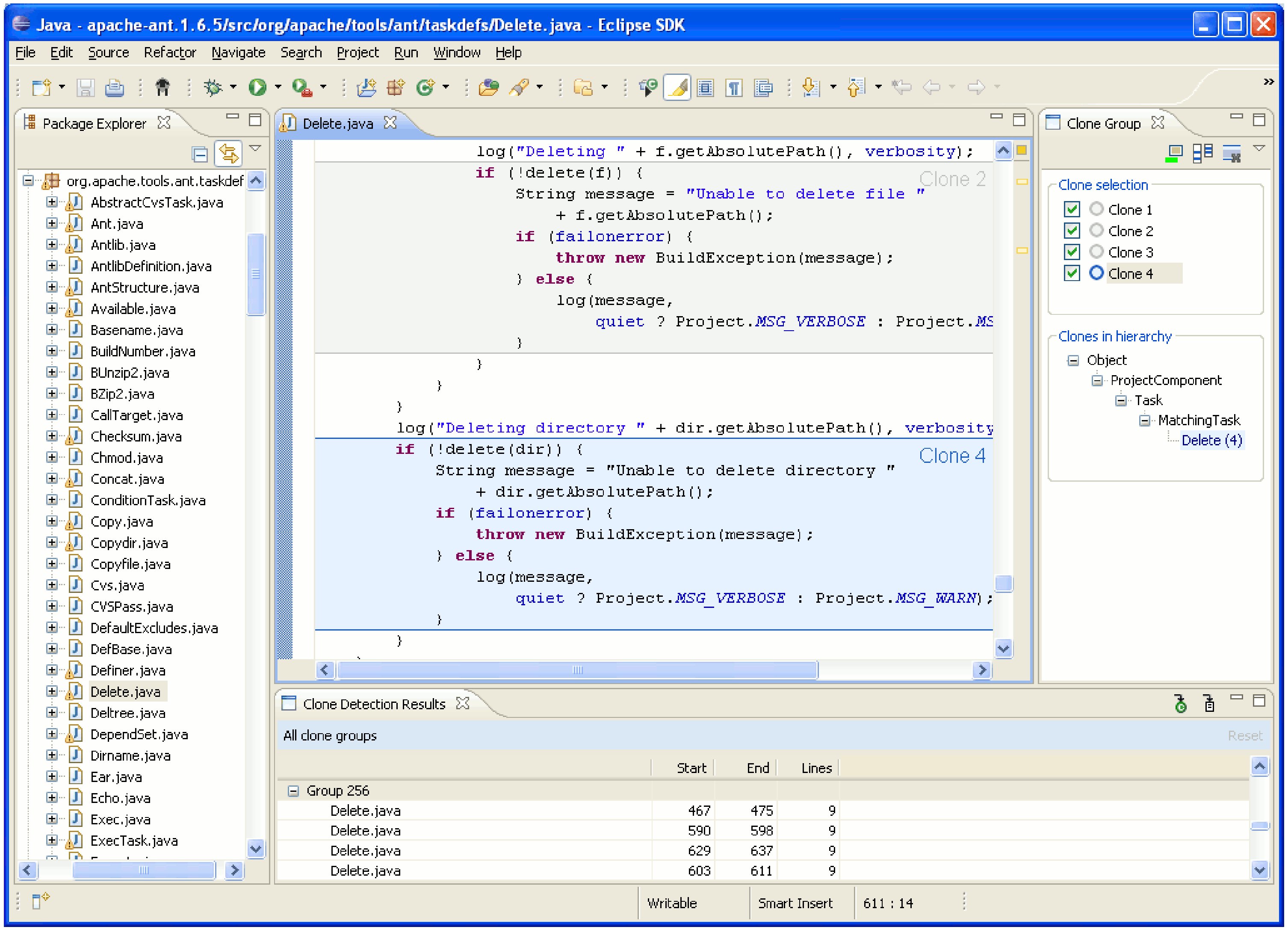
Clone Differences	Refactorable	7	4	8
	Not Refactorable	7	5	7

- Programmers only refactored a sub-clone even when the entire clone was refactorable

Conclusion

- We observed the actual refactoring of clones by evaluating source code changes between multiple versions
  - In various instances only part of the reported clone (i.e., sub-clone) was refactored
- We conclude that sub-clone refactoring should be included in the clone maintenance process
- Future Work
  - Individual evaluation of other clone detection tools
  - Provide support for sub-clone refactoring in an IDE

CeDAR plug-in


Java - apache-ant.1.6.5/src/org/apache/tools/ant/taskdefs/Delete.java - Eclipse SDK
File Edit Source Refactor Navigate Search Project Run Window Help
Package Explorer
Delete.java
Clone Group
Clone Detection Results
Reset

org.apache.tools.ant.taskdef
- AbstractCvsTask.java
- Ant.java
- Antlib.java
- AntlibDefinition.java
- AntStructure.java
- Available.java
- Basename.java
- BuildNumber.java
- BUnzip2.java
- BZip2.java
- CallTarget.java
- Checksum.java
- Chmod.java
- Concat.java
- ConditionTask.java
- Copy.java
- Copydir.java
- Copyfile.java
- Cvs.java
- CVSPass.java
- DefaultExcludes.java
- DefBase.java
- Definer.java
- Delete.java
- Deltree.java
- DependSet.java
- Dirname.java
- Ear.java
- Echo.java
- Exec.java
- ExecTask.java

```
                log("Deleting " + f.getAbsolutePath(), verbosity);
                if (!delete(f)) {                                        Clone 2
                    String message = "Unable to delete file "
                        + f.getAbsolutePath();
                    if (failonerror) {
                        throw new BuildException(message);
                    } else {
                        log(message,
                            quiet ? Project.MSG_VERBOSE : Project.MS
                    }
                }
            }
        }
        log("Deleting directory " + dir.getAbsolutePath(), verbosity
        if (!delete(dir)) {                                              Clone 4
            String message = "Unable to delete directory "
                + dir.getAbsolutePath();
            if (failonerror) {
                throw new BuildException(message);
            } else {
                log(message,
                    quiet ? Project.MSG_VERBOSE : Project.MSG_WARN);
            }
        }
```

Clone selection
- ✓ ○ Clone 1
- ✓ ○ Clone 2
- ✓ ○ Clone 3
- ✓ ● Clone 4

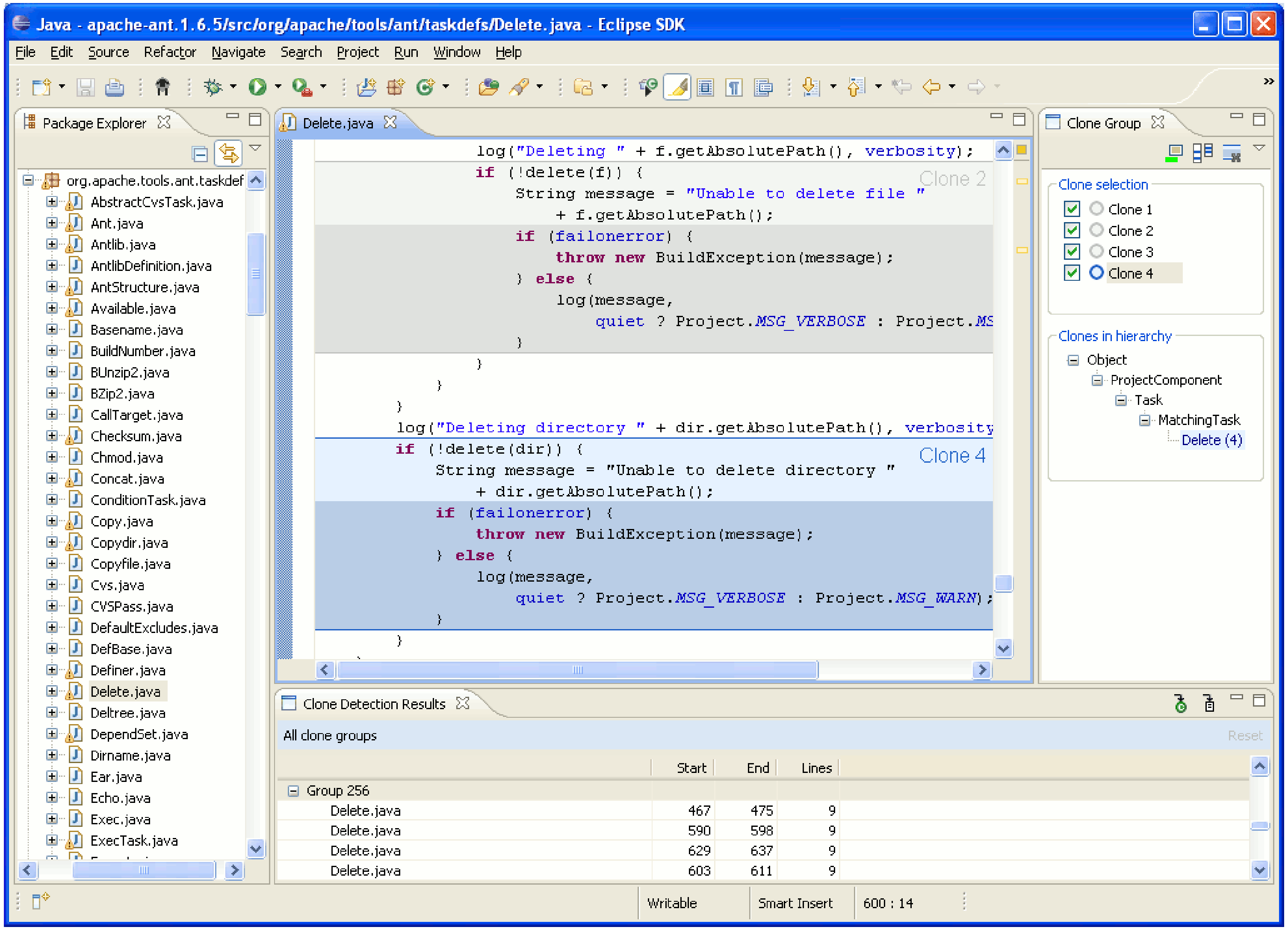
Clones in hierarchy
- Object
  - ProjectComponent
    - Task
      - MatchingTask
        - Delete (4)

All clone groups

	Start	End	Lines
Group 256			
Delete.java	467	475	9
Delete.java	590	598	9
Delete.java	629	637	9
Delete.java	603	611	9

Writable   Smart Insert   611 : 14

Sub-clones in CeDAR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Package Explorer:

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Delete.java:

```
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                    } else {
                        log(message,
                            quiet ? Project.MSG_VERBOSE : Project.MS
                    }
                }
            }
        }
        log("Deleting directory " + dir.getAbsolutePath(), verbosity
        if (!delete(dir)) {                                          Clone 4
            String message = "Unable to delete directory "
                + dir.getAbsolutePath();
            if (failonerror) {
                throw new BuildException(message);
            } else {
                log(message,
                    quiet ? Project.MSG_VERBOSE : Project.MSG_WARN);
            }
        }
```

Clone Group:

Clone selection
- ✓ ○ Clone 1
- ✓ ○ Clone 2
- ✓ ○ Clone 3
- ✓ ● Clone 4

Clones in hierarchy
- Object
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    - Task
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        - Delete (4)

Clone Detection Results

All clone groups — Reset

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Delete.java	467	475	9
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Thank you

- Personal:
  - http://www.cis.uab.edu/tairasr
- Code Clones Literature:
  - http://www.cis.uab.edu/tairasr/clones/literature
- SoftCom Laboratory:
  - http://www.cis.uab.edu/softcom