LARA Tutorial

6. Java-to-Java Weaving

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ANTAREX 10^{18}

SPeCS
Special-Purpose Computing Systems, languages and tools

Objectives

- Demonstrate LARA in the context of Java
- Report static information
- Capture and report runtime information
- Transform code to allow adaptation

Some Information

- **Kadabra**
  - LARA + Spoon*
  - Ongoing Work!
  - http://specs.fe.up.pt/tools/kadabra/

- Example Used
  - Median smooth

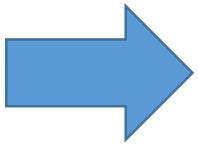
*Spoon library: http://spoon.gforge.inria.fr/

6.1 Static Code Report

- Print static information regarding
  - No. Of : files, **classes**, **methods** and calls
  - Loop and call information

New joinpoints: class, interface
Join point rename: function → method

```
select file.class.method.loop end
apply
  num_loops++;
  if($loop.type == 'for') {
   for_loops++;
   if($loop.isInnermost) {
     num_loops_innermost++;
     for_innermost_loops++;
   }
  }
  ...
end
```



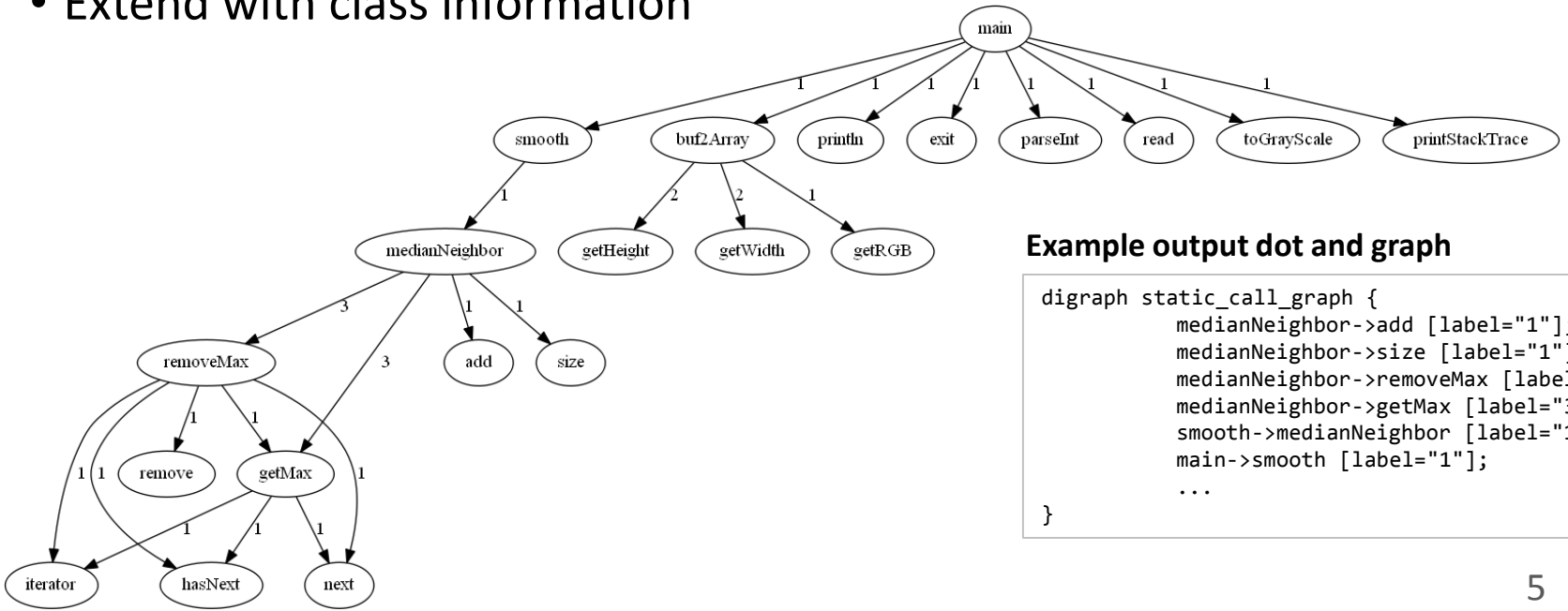
Example output:

```
-== [ Loop Information ] ==-

==============================
Type        Total    Innermost
------------------------------
For         6        6
While       0        2
Do-While    0        0
Foreach     7        0
------------------------------
Total       13       8
==============================
```

6.2 Static Call Graph - Goals

- Print a static call graph in dot format
- Extend with class information



Example output dot and graph

```
digraph static_call_graph {
            medianNeighbor->add [label="1"];
            medianNeighbor->size [label="1"];
            medianNeighbor->removeMax [label="3"];
            medianNeighbor->getMax [label="3"];
            smooth->medianNeighbor [label="1"];
            main->smooth [label="1"];
            ...
}
```

6.2 Static Call Graph - Strategy

- Select pairs method→call
- Count occurences of each pair
- Iterate LaraObject and print

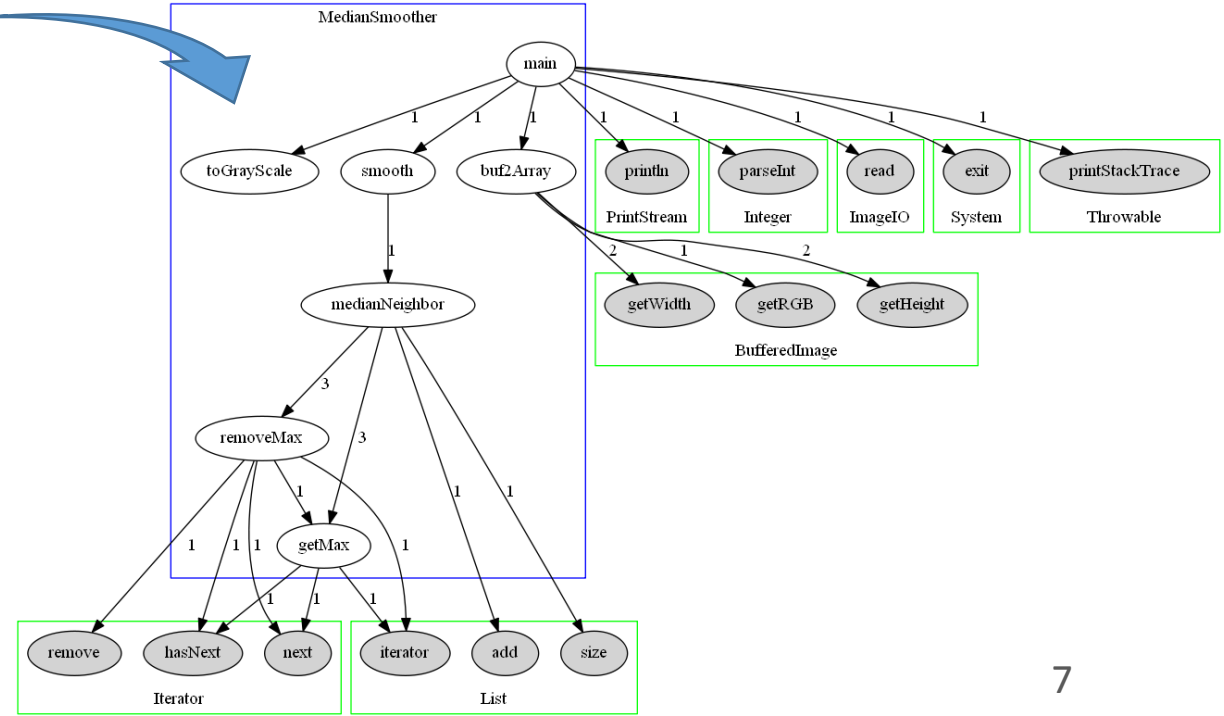
```
var call_graph = new LaraObject();
select class.method.call end
apply
  call_graph.inc($method.name, $call.name);
end
```

```
println('digraph static_call_graph {\n');
for (f in call_graph) {
 for (c in call_graph[f]) {
   println('\t' + f + '->' + c +
     ' [label="' + call_graph[f][c] + '"];');
 }
}
println('}');
```

6.2.1 Extended Static Call Graph - Strategy

- Add class information as clusters

```
subgraph cluster_MedianSmoother {
   label="MedianSmoother";
   color=blue;
   getMax
   medianNeighbor
   buf2Array
   smooth
   toGrayScale
   removeMax
   main
}
```



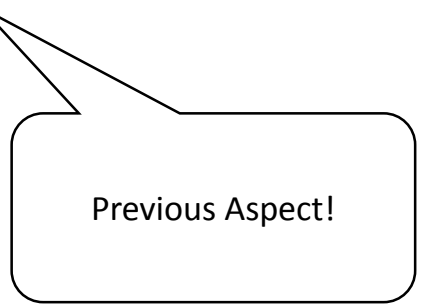
6.3 Dynamic Call Graph (DCG) – Goals

- Capture a call graph of an execution
- Generate dot code to represent the graph
- Extend with class information

6.3 Dynamic Call Graph (DCG) – Strategy

- Gather class→method information

```
call GetClasses();
```



6.3 Dynamic Call Graph (DCG) – Strategy

- Gather class→method information

- Insert a Monitor
  - Create new class
  - Add field in `$class`

    ```
    CountingMonitorList monitor;
    ```

- Add graph printer method

```
$class.exec newMethod(...,'void','printCallGraph',[]);
```

```
select class{name~=targetClass} end
apply
  call CountingMonitorList($class);
end
```

```
public class CountingMonitorList {
    private int[] counter;
    public CountingMonitorList(int size) {
        counter = new int[size];
    }
    public int get(int id) {
        return counter[id];
    }

    public void increment(int id) {
        counter[id]++;
    }
    ...
}
```

6.3 Dynamic Call Graph (DCG) – Strategy

- Gather class→method information

- Insert a Monitor
  - Create new class
  - Add field in `$class`
  - Add graph printer method

- Select method → call pairs
  - Define id for each pair
  - Use id to increment before calls

```
select method.call end
 apply
  var id = tuple.getId($method.name, $call.name);
  var incrementCode = monitor.increment(id);
  insert before '[[incrementCode]]';
 end
end
```

```
monitor.increment(5);
removeMax(values);
```

6.3 Dynamic Call Graph (DCG) – Strategy

- Gather class→method information
- Insert a Monitor
  - Create new class
  - Add field in `$class`
  - Add graph printer method
- Select method → call pairs
  - Define id for each pair
  - Use id to increment before calls
- Insert code in printer to output dot

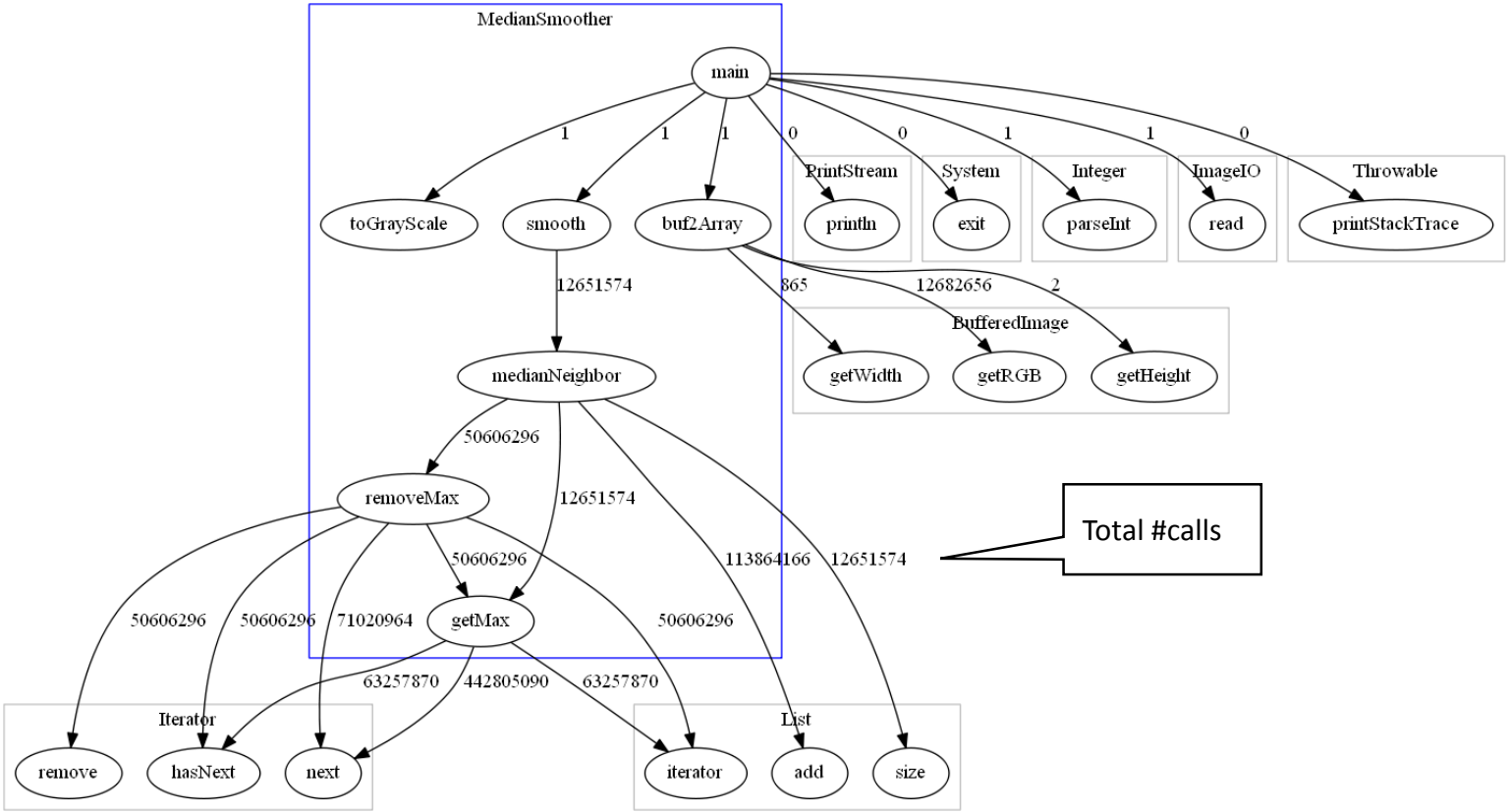
```
select class.method{'printCallGraph'}.body end
 apply
   call printer:GenerateDCGPrinter(monitor, pair,
                                   classes, apis);
   insert replace '[[printer.code]]';
 end
```

```
aspectdef GenerateDCGPrinter
  input monitor, obj, methods, apis  end
  output code end
  code  = 'int value;\n'
  code += '\tSystem.out.println("digraph DCG {';

  for(var c in methods) {

    code += '\tSystem.out.println(...);';
    ...
end
```

6.3 Dynamic Call Graph (DCG) – Output



6.4 Method Call Adaptation – Goals

- Several algorithms to calculate median
  - Removing half max. values (current approach)
  - Counting sort
  - Sorting Network
- Replace median method call
- Select best algorithm based on arguments

```
int[][] smooth(int[][] input, int kernelSize,...) {
 int limit = kernelSize / 2;
 int[][] outputArrays = new int[height][width];
 for (int i = limit ; i < (height - limit) ; ++i) {
    for (int j = limit ; j < (width - limit) ; ++j) {
     outputArrays[i][j] = medianNeighbor(input, kernelSize);
    }
 }
 return outputArrays;
}
```

6.4 Method Call Adaptation – Strategy

- Extract a functional interface (FI)*

```
public static int[][] smooth(int[][] input, int kernelSize, int width, int height)
    int limit = kernelSize / 2;
    int[][] outputArrays = new int[height][width];
    for (int i = limit ; i < (height - limit) ; ++i) {
        for (int j = limit ; j < (width - limit) ; ++j) {
            outputArrays[i][j] = MedianSmoother.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}
```

```
public static int[][] smooth(int[][] input, int kernelSize, int width, int height)
    int limit = kernelSize / 2;
    int[][] outputArrays = new int[height][width];
    for (int i = limit ; i < (height - limit) ; ++i) {
        for (int j = limit ; j < (width - limit) ; ++j) {
            outputArrays[i][j] = MedianSmoother.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}
```

```
public static interface IMedianNeighbor {
    public int medianNeighbor(int[][] input, int kernelSize, int width,
                              int height, int y, int x);
}
```

```
call ExtractFuncInterface('MedianSmoother', 'medianNeighbor');
```

* Functional Interfaces: https://docs.oracle.com/javase/8/docs/api/java/lang/FunctionalInterface.html
https://www.oreilly.com/learning/java-8-functional-interfaces

6.4 Method Call Adaptation – Strategy (2)

- Create a new field of type FI

```
public static int[][] smooth(int[][] input, int kernelSize, int width, int height)
    int limit = kernelSize / 2;
    int[][] outputArrays = new int[height][width];
    for (int i = limit ; i < (height - limit) ; ++i) {
        for (int j = limit ; j < (width - limit) ; ++j) {
            outputArrays[i][j] = MedianSmoother.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}
```

```
public static int[][] smooth(int[][] input, int kernelSize, int width, int height)
    int limit = kernelSize / 2;
    int[][] outputArrays = new int[height][width];
    for (int i = limit ; i < (height - limit) ; ++i) {
        for (int j = limit ; j < (width - limit) ; ++j) {
            outputArrays[i][j] = MedianSmoother.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}
```

```
public static interface IMedianNeighbor {
    public int medianNeighbor(int[][] input, int kernelSize, int width,
                              int height, int y, int x);
}

static IMedianNeighbor medianNeighbor = MedianSmoother::medianNeighbor;
```

```
$class.exec newField(['static'], 'IMedianNeighbor', 'medianNeighbor', MedianSmoother::medianNeighbor);
```

6.4 Method Call Adaptation – Strategy (3)

- Replace call with field invocation

```
$call.def target = 'medianNeighbor';
```

```
public static int[][] smooth(int[][] input, int kernelSize, int width, int height)
    int limit = kernelSize / 2;
    int[][] outputArrays = new int[height][width];
    for (int i = limit ; i < (height - limit) ; ++i) {
        for (int j = limit ; j < (width - limit) ; ++j) {
            outputArrays[i][j] = MedianSmoother.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}
```

```
public static int[][] smoo          input, int kernelSize, int width, int height)
    int limit = kernelSize /
    int[][] outputArrays = new          eight][width];
    for (int i = limit ; i < (he        t - limit) ; ++i) {
        for (int j = limit ; j <        idth - limit) ; ++j) {
            outputArrays[i][j] = medianNeighbor.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}


public static interface IMedianNeighbor {
    public int medianNeighbor(int[][] input, int kernelSize, int width,
                              int height, int y, int x);
}

static IMedianNeighbor medianNeighbor = MedianSmoother::medianNeighbor;
```

6.4.1 Switch Call – Strategy

- Insert a switch to select between versions
- Insert versions
  - Sorting network: kernelSize == 3
  - Counting sort: kernelSize == 5 || 7

```
codedef SwitchVersion(fieldName, className, defaultMethod) %{
  switch(kernelSize){
    case 3:
      [[fieldName]] = [[className]]::sortingNetwork; break;
    case 5:
    case 7:
      [[fieldName]] = [[className]]::countingSort; break;
    default: [[fieldName]] = [[className]]::[[defaultMethod]]; break;
  }}%
end
```

6.4.1 Switch Call – Diff

```
public static int[][] smooth(int[][] input, int kernelSize, int width, int height)
    int limit = kernelSize / 2;
    int[][] outputArrays = new int[height][width];
    for (int i = limit ; i < (height - limit) ; ++i) {
        for (int j = limit ; j < (width - limit) ; ++j) {
            outputArrays[i][j] = MedianSmoother.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}
```

```
public static int[][] smooth(int[][] input, int kernelSize, int width, int height)
    switch(kernelSize){
            case 3: medianNeighbor = MedianSmoother::sortingNetwork; break;
            case 5:
            case 7:
                    medianNeighbor = MedianSmoother::countingSort; break;
            default: medianNeighbor = MedianSmoother::medianNeighbor; break;
    };
    int limit = kernelSize / 2;
    int[][] outputArrays = new int[height][width];
    for (int i = limit ; i < (height - limit) ; ++i) {
        for (int j = limit ; j < (width - limit) ; ++j) {
            outputArrays[i][j] = medianNeighbor.medianNeighbor(input, kernelSize,
                                                               width, height, i, j);
        }
    }
    return outputArrays;
}

public static int medianNeighbor(int[][] input, int kernelSize, int width,
                                 int height, int y, int x) {
    ...
}


public static interface IMedianNeighbor {
    public int medianNeighbor(int[][] input, int kernelSize, int width,
                              int height, int y, int x);
}

static IMedianNeighbor medianNeighbor = MedianSmoother::medianNeighbor;
```

```
insert before SwitchVersion('medianNeighbor', //field
                            'MedianSmoother', //class
                            'medianNeighbor');//default
```

6.4.2 Map Call – Strategy

- New class mapping kernelSize → method
- Add default versions
- Insert getter to the best version

Can add/reassign new versions at runtime!

```
call methodCaller: NewMappingClass(interface, baseName, 'int');

//Add some default versions
var versionsCode = 'put(3, MedianSmoother::sortingNetwork);';
...
$mapClass.exec insertStatic(versionsCode);

var getBestVersionCode = methodCaller.get('kernelSize', defaultMethod);
//at the beginning of smooth assign the best version
$first_stmt.insert before '[[fieldName]] = [[getBestVersionCode]]';
```

6.4.2 Map Call – Mapping class

```
call methodCaller: NewMappingClass(interface, baseName, 'int');
```

```
1. public class MedianNeighborCaller {
2.     final public static Map<Integer, IMedianNeighbor> map= new ConcurrentHashMap<>();
3.
4.     public static void put(int key, IMedianNeighbor IMedianNeighbor) {
5.         map.put(key,IMedianNeighbor);
6.     }
7.
8.     public static boolean contains(int key) {
9.         return map.containsValue(key);
10.    }
11.
12.    public static IMedianNeighbor get(int key, IMedianNeighbor defaultMethod) {
13.        return map.getOrDefault(key, defaultMethod);
14.    }
15. }
```

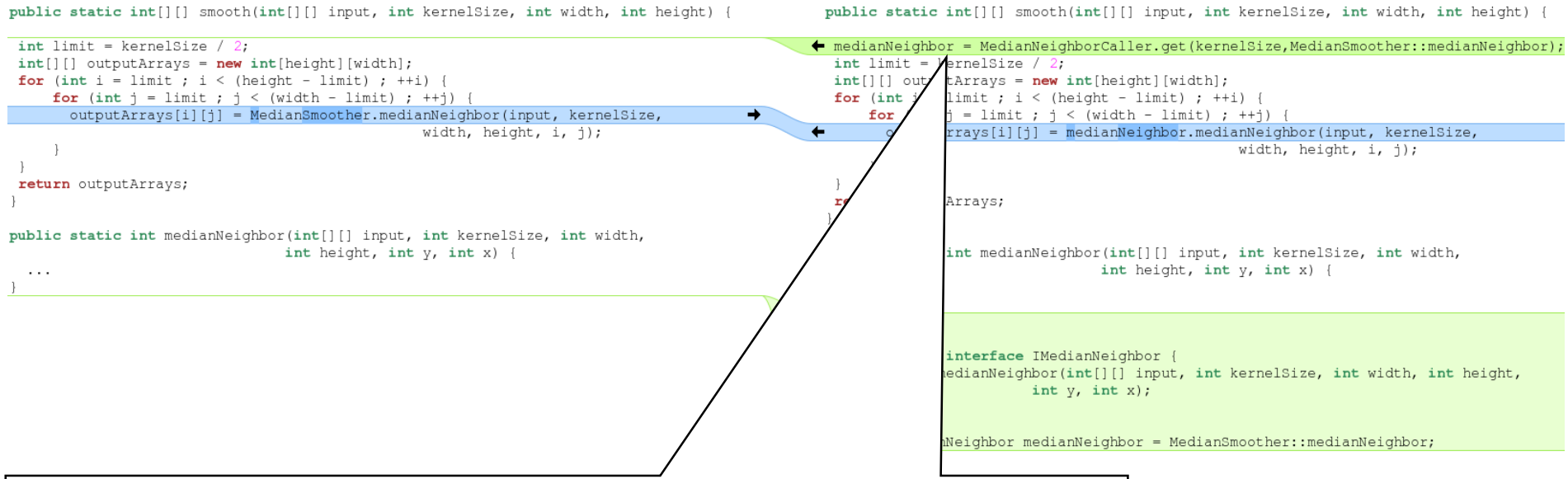
6.4.2 Map Call – Mapping class

```
var versionsCode = 'put(3, MedianSmoother::sortingNetwork);';
...
$mapClass.exec insertStatic(versionsCode);
```

```
1. public class MedianNeighborCaller {
2.     static {
3.         put(3, MedianSmoother::sortingNetwork);
4.         put(5, MedianSmoother::countingSort);
5.         put(7, MedianSmoother::countingSort);
6.     }
7.
8.     final public static Map<Integer, IMedianNeighbor> map= new ConcurrentHashMap<>();
9.
10.    public static void put(int key, IMedianNeighbor IMedianNeighbor) {
11.        map.put(key,IMedianNeighbor);
12.    }
13.
14.    public static IMedianNeighbor get(int key, IMedianNeighbor defaultMethod) {
15.        return map.getOrDefault(key, defaultMethod);
16.    }
17. }
```

Default Versions

6.4.2 Map Call – Diff




```
var getBestVersionCode = methodCaller.get('kernelSize', 'MedianSmoother::medianNeighbor');
$first_stmt.insert before '[[fieldName]] = [[getBestVersionCode]]';
```

Takeaway Points

- Some aspects can be reused between tools
  - Minor changes: function→method
- Code can be transformed to comprise adaptation
- Provides mechanisms for runtime adaptability
  - Through static insertion/transformation