Formal Methods for Java

Lecture 28: Covering Java Programs with Pathfinder

Jochen Hoenicke

Software Engineering
Albert-Ludwigs-University Freiburg

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Testing Programs with Java Pathfinder

Java Pathfinder on an example

JPF .. *the swiss army knife of Java™ verification*

http://babelfish.arc.nasa.gov/trac/jpf/wiki

- Uses model-checking techniques.
- Exhaustive testing.
- Lets try it on our buggy Heap.

Buggy Heap

Remember the heap class from lecture 5:

```
public class Heap implements PriorityQueue {
    private Comparable[] elems;
    private int numElems;
    /*@ private invariant ...;
      @ private invariant
      @   (\forall int i; 0 <= i && i < numElems;
      @     (2*i+1 < numElems ==> elems[i].compareTo(elems[2*i+1]) <= 0)
      @  && (2*i+2 < numElems ==> elems[i].compareTo(elems[2*i+2]) <= 0));
      @*/

    public void enqueue(/*@non_null@*/ Comparable o) {
        ...
        int parent = pos / 2;
```

- Node i has children $2 * i + 1$ and $2 * i + 2$.
- Parent of pos is computed by $pos/2$, but $(2 * i + 2)/2 = i + 1$.
- Bug was hard to find with testing.

Test Code

```
public static void main(String[] param) throws IOException {
    BufferedReader reader =
        new BufferedReader(new InputStreamReader(System.in));
    PriorityQueue pq = new Heap();
    while (true) {
        String input = reader.readLine();
        if (input.charAt(0) == 'x') break;
        if (input.charAt(0) == 'r') {
            if (!pq.isEmpty()) {
                System.out.println("first␣is␣"+pq.removeFirst());
        } } else {
            pq.enqueue(Integer.parseInt(input));
        }
    }
}
```

Running Test code through JPF

- JPF does not implement *System*.in.
  ⇒ reports *NullPointerException* on *readLine*().
- Use Pathfinder API:
  - *Verify*.*getBoolean*(): get a boolean value
  - *Verify*.*getInt*("name"): get an integer configured by name.
- Idea:
  - Guess number of iterations using *getInt*("round").
  - Use *Verify*.*getBoolean*() to decide whether to enqueue or dequeue.
  - Use *Verify*.*getInt*("value") for data to insert.

Test with Pathfinder-API

```
import gov.nasa.jpf.jvm.Verify;

public static void main(String[] param) {
    PriorityQueue pq = new Heap();
    int rounds = Verify.getInt("rounds");
    for (int i = 0; i < rounds; i++) {
        if (Verify.getBoolean()) {
            int value = Verify.getInt("value");
            pq.enqueue(value);
        } else {
            Verify.ignoreIf(pq.isEmpty());
            System.out.println("first␣is␣" + pq.removeFirst());
        }
    }
}
```

JPF Example

Demo