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Hand in solutions via email to
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until 15.01.2013 (only Java sources and
PDFs accepted).

Paper submissions possible after the lecture.

Tutorials for “Formal methods for Java” Exercise sheet 9

Exercise 1: Jahob Syntax

Translate the JML annotations in the following program into Jahob syntax.

```
class IntKey {  
    int value;  
}
```

```
public class BubbleSort {  
    /*@ requires arr.length > 0 &&& (\forallall int i; i >= 0 &&& i < arr.length; arr[i] != null);  
       @ ensures (\forallall int k, l; 0 <= k &&& k <= l &&& l < arr.length;  
       @          arr[k].value <= arr[l].value);  
    @*/  
    public void sort(/*@ non_null */ IntKey[] arr) {  
        /*@ loop_invariant i >= 0 &&& i < arr.length;  
           @ loop_invariant (\forallall int i; i >= 0 &&& i < arr.length; arr[i] != null);  
           @ loop_invariant (\forallall int k, l; i <= k &&& k <= l &&& l < arr.length;  
           @          arr[k].value <= arr[l].value);  
           @ loop_invariant (\forallall int k, l;  
           @          0 <= k &&& k <= i &&& i < l &&& l < arr.length;  
           @          arr[k].value <= arr[l].value);  
           @  
           @*/  
        for (int i = arr.length-1; i > 0; i--) {  
            /*@ loop_invariant i >= 0 &&& i < arr.length;  
               @ loop_invariant (\forallall int i; i >= 0 &&& i < arr.length; arr[i] != null);  
               @ loop_invariant j >= 0 &&& j <= i;  
               @ loop_invariant (\forallall int k, l; i <= k &&& k <= l &&& l < arr.length;  
               @          arr[k].value <= arr[l].value);  
               @ loop_invariant (\forallall int k, l;  
               @          0 <= k &&& k <= i &&& i < l &&& l < arr.length;  
               @          arr[k].value <= arr[l].value);  
            }  
        }  
    }  
}
```

```

    @ loop_invariant (\ forall int k; 0 <= k && k < j;
    @                               arr[k].value <= arr[j].value);
    @*/
    for (int j = 0; j < i; j++) {
        if (arr[j].value >= arr[j+1].value) {
            IntKey tmp = arr[j];
            arr[j] = arr[j+1];
            arr[j+1] = tmp;
        }
    }
}

```