**Name : Siddhant Kotak**

**Student ID : 202201410**

**Course : IT 314 Software Engineering**

**Professor : Saurabh Tiwari**

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# Lab : Program Inspection, Debugging and Static Analysis

# Merge Sort

### Given code :

```
// This program implements the merge sort algorithm for
// arrays of integers.

import java.util.*;

public class MergeSort {
   public static void main(String[] args) {
      int[] list = {14, 32, 67, 76, 23, 41, 58, 85};
      System.out.println("before: " + Arrays.toString(list));
      mergeSort(list);
      System.out.println("after:  " + Arrays.toString(list));
   }

   // Places the elements of the given array into sorted order
   // using the merge sort algorithm.
   // post: array is in sorted (nondecreasing) order
   public static void mergeSort(int[] array) {
      if (array.length > 1) {
         // split array into two halves
         int[] left = leftHalf(array+1);
         int[] right = rightHalf(array-1);

         // recursively sort the two halves
         mergeSort(left);
         mergeSort(right);

         // merge the sorted halves into a sorted whole
```

```
        merge(array, left++, right--);
    }
}

// Returns the first half of the given array.
public static int[] leftHalf(int[] array) {
    int size1 = array.length / 2;
    int[] left = new int[size1];
    for (int i = 0; i < size1; i++) {
        left[i] = array[i];
    }
    return left;
}

// Returns the second half of the given array.
public static int[] rightHalf(int[] array) {
    int size1 = array.length / 2;
    int size2 = array.length - size1;
    int[] right = new int[size2];
    for (int i = 0; i < size2; i++) {
        right[i] = array[i + size1];
    }
    return right;
}

// Merges the given left and right arrays into the given
// result array.  Second, working version.
// pre : result is empty; left/right are sorted
// post: result contains result of merging sorted lists;
public static void merge(int[] result,
                         int[] left, int[] right) {
```

```
        int i1 = 0;   // index into left array
        int i2 = 0;   // index into right array

        for (int i = 0; i < result.length; i++) {
          if (i2 >= right.length || (i1 < left.length &&
                left[i1] <= right[i2])) {
            result[i] = left[i1];    // take from left
            i1++;
          } else {
            result[i] = right[i2];   // take from right
            i2++;
          }
        }
      }
    }
```

Input: before 14 32 67 76 23 41 58 85

after 14 23 32 41 58 67 76 85

## Program Inspection for Merge Sort

1. **How many errors are there in the program? Mention the errors you have identified.**

- **Errors Identified: 3**
    - **Incorrect Array Manipulation:**
        - In the mergeSort method, the lines int[] left = leftHalf(array+1); and int[] right = rightHalf(array-1); are incorrect. You cannot add or subtract from an array directly in Java. Instead, the code should pass a subarray of the original array to these methods.
    - **Incorrect Merge Method Call:**
        - The line merge(array, left++, right--); contains incorrect usage of the ++ and -- operators. These operators cannot be used on array references in this context. Instead, it should just be merge(array, left, right);.

- **Merge Method Logic:**
    - The merge function should operate on a temporary array (the result array) to hold the merged values. The merge function is defined correctly, but it's not utilized properly in the mergeSort method.

**2. Which category of program inspection would you find more effective?**

- **Effective Category:**
    - **Control-Flow Errors**: This category is particularly effective here since it deals with the logical flow of the program, especially in how the recursive calls and array handling are managed.

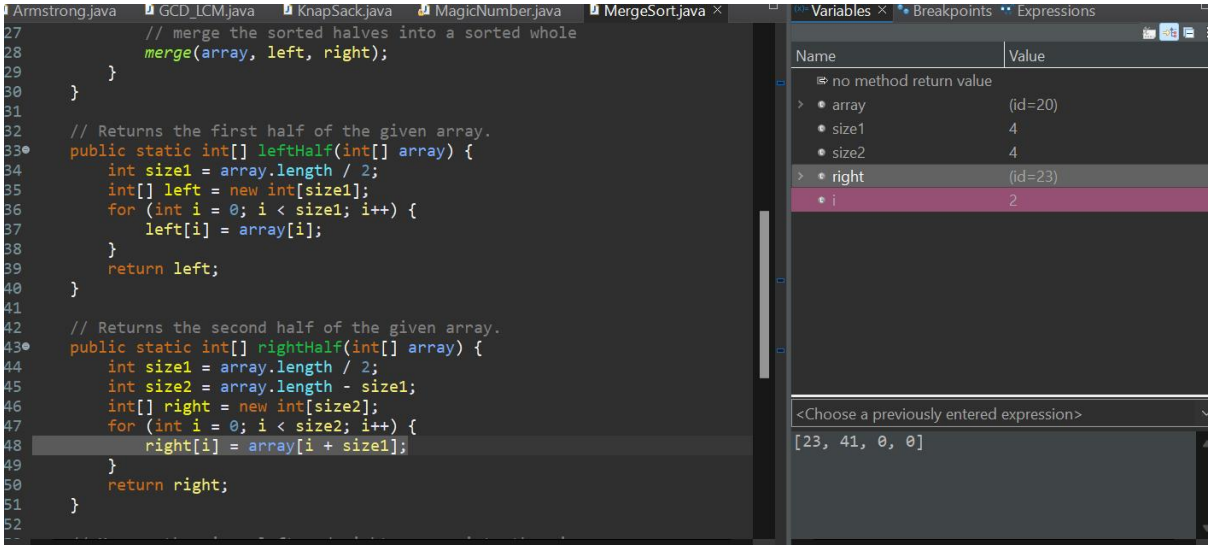
**3. Which type of error you are not able to identify using the program inspection?**

- **Errors Not Identified:**
    - **Semantic Errors in Array Handling**: Program inspections can miss semantic errors like those arising from incorrect manipulation or interpretation of array indices, especially when it comes to passing array sections or creating subarrays.

**4. Is the program inspection technique worth applicable?**

- **Applicability of Program Inspection:**
    - Yes, the program inspection technique is worth applying. It aids in identifying structural issues and potential run-time exceptions, which ultimately contributes to higher code quality. However, it's important to supplement it with other testing methods to catch logical and semantic errors.

# Code Debugging




```
27            // merge the sorted halves into a sorted whole
28            merge(array, left, right);
29        }
30    }
31
32    // Returns the first half of the given array.
33    public static int[] leftHalf(int[] array) {
34        int size1 = array.length / 2;
35        int[] left = new int[size1];
36        for (int i = 0; i < size1; i++) {
37            left[i] = array[i];
38        }
39        return left;
40    }
41
42    // Returns the second half of the given array.
43    public static int[] rightHalf(int[] array) {
44        int size1 = array.length / 2;
45        int size2 = array.length - size1;
46        int[] right = new int[size2];
47        for (int i = 0; i < size2; i++) {
48            right[i] = array[i + size1];
49        }
50        return right;
51    }
52
```

```
51    }
52
53    // Merges the given left and right arrays into the given
54    // result array.  Second, working version.
55    // pre : result is empty; left/right are sorted
56    // post: result contains result of merging sorted lists;
57    public static void merge(int[] result,
58                             int[] left, int[] right) {
59        int i1 = 0;   // index into left array
60        int i2 = 0;   // index into right array
61
62        for (int i = 0; i < result.length; i++) {
63            if (i2 >= right.length || (i1 < left.length &&
64                    left[i1] <= right[i2])) {
65                result[i] = left[i1];    // take from left
66                i1++;
67            } else {
68                result[i] = right[i2];   // take from right
69                i2++;
70            }
71        }
72    }
73 }
74
```

```
Console × Problems Debug Shell
<terminated> MergeSort [Java Application] C:\Program Files\Java\jdk-22\bin\javaw.exe (20 Oct 2024, 6:27:47 pm – 6:27:47 pm) [pid: 22200
before: [14, 32, 67, 76, 23, 41, 58, 85]
after:  [14, 23, 32, 41, 58, 67, 76, 85]
```

**Errors Identified**

1. **Incorrect Method Calls for Splitting the Array:**
    - **Original Line:** int[] left = leftHalf(array + 1);
    - **Correction:** Change to int[] left = leftHalf(array); (You should pass the entire array without modifying it.)
    - **Original Line:** int[] right = rightHalf(array - 1);

- **Correction:** Change to int[] right = rightHalf(array); (Again, pass the entire array.)

2. **Invalid Merge Function Call:**
    - **Original Line:** merge(array, left++, right--);
    - **Correction:** Change to merge(array, left, right); (Post-increment and post-decrement do not apply to arrays.)

**Breakpoints Needed**

You can set breakpoints at the following lines for effective debugging:

- **Line 15:** To check how the left array is created.
- **Line 16:** To check how the right array is created.
- **Line 21:** To verify if the merge is done correctly.

**Steps to Fix the Errors**

1. **Change the method calls** to leftHalf(array) and rightHalf(array) to avoid modifying the input array.
2. **Update the merge function call** to merge(array, left, right); instead of using post-increment and post-decrement.

**Fixed Code**

```
// This program implements the merge sort algorithm for arrays of integers.
import java.util.*;
public class MergeSort {
  public static void main(String[] args) {
    int[] list = {14, 32, 67, 76, 23, 41, 58, 85};
    System.out.println("before: " + Arrays.toString(list));
    mergeSort(list);
    System.out.println("after: " + Arrays.toString(list));
  }

  // Places the elements of the given array into sorted order using the merge sort algorithm.
  // post: array is in sorted (nondecreasing) order
  public static void mergeSort(int[] array) {
    if (array.length > 1) {
      // split array into two halves
      int[] left = leftHalf(array); // Fixed
```

```
        int[] right = rightHalf(array); // Fixed
        // recursively sort the two halves
        mergeSort(left);
        mergeSort(right);
        // merge the sorted halves into a sorted whole
        merge(array, left, right); // Fixed
    }
}

// Returns the first half of the given array.
public static int[] leftHalf(int[] array) {
    int size1 = array.length / 2;
    int[] left = new int[size1];
    for (int i = 0; i < size1; i++) {
        left[i] = array[i];
    }
    return left;
}

// Returns the second half of the given array.
public static int[] rightHalf(int[] array) {
    int size1 = array.length / 2;
    int size2 = array.length - size1;
    int[] right = new int[size2];
    for (int i = 0; i < size2; i++) {
        right[i] = array[i + size1];
    }
    return right;
}

// Merges the given left and right arrays into the given result array.
```

```
    // pre : result is empty; left/right are sorted
    // post: result contains result of merging sorted lists
    public static void merge(int[] result, int[] left, int[] right) {
        int i1 = 0; // index into left array
        int i2 = 0; // index into right array
        for (int i = 0; i < result.length; i++) {
            if (i2 >= right.length || (i1 < left.length && left[i1] <= right[i2])) {
                result[i] = left[i1]; // take from left
                i1++;
            } else {
                result[i] = right[i2]; // take from right
                i2++;
            }
        }
    }
}
```

**Input and Output**

- **Input:**
    - Before sorting: {14, 32, 67, 76, 23, 41, 58, 85}
- **Output:**

After sorting: {14, 23, 32, 41, 58, 67, 76, 85}