SOFTWARE ENGINEERING

IT-314

Lab Session VII

Program Inspection, Debugging and Static Analysis

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Task I. PROGRAM INSPECTION

GitHub Code Link: Robin Hood Hashing

1. **Number of Errors in the Program:**

Category A: Data Reference Issues:

- Uninitialized Variables:
    - The variables mHead and mListForFree are set to nullptr, but they are not consistently reset after memory deallocation, which could lead to dangling pointers or accessing uninitialized memory.

```
T* allocate() {
    T* tmp = mHead;
    if (!tmp) {
        tmp = performAllocation();
    }
    mHead = reinterpret_cast_no_cast_align_warning<T*>(tmp);
    return tmp;
}
```

- Array Bound Violations:
    - Functions like shiftUp and shiftDown do not have boundary checks to ensure that the array indices remain valid during execution.

```
while (--idx != insertion_idx) {
        mKeyVals[idx] = std::move(mKeyVals[idx - 1]);
    }
```

- Dangling Pointers:
    - In the BulkPoolAllocator, the reset() method frees memory but doesn't assign the pointer back to nullptr, leaving behind a potential dangling pointer.
- Type Mismatches:
    - The usage of reinterpret_cast_no_cast_align_warning involves casting memory areas without verifying the types or attributes, potentially leading to issues.

Category B: Data Declaration Issues:

- Possible Data Type Conflicts:
    - The hash_bytes function performs several type casts during its hashing operations. If the data types differ in size or attributes, this could result in unintended behavior.
- Similar Variable Names:
    - Variables like mHead, mListForFree, and mKeyVals are quite similar in name, which can cause confusion during code modification or debugging.

Category C: Computational Issues:

- Integer Overflow:
    - The calculations in the hash_bytes function may encounter overflow when performing multiple shifts and multiplications on large integers.
- Off-by-One Errors:
    - The conditions in loops like shiftUp and shiftDown may cause off-by-one errors if the data structure size is not handled properly.
    - For example, while (--idx != insertion_idx) could result in an off-by-one mistake.

Category D: Comparison Issues:

- Improper Boolean Comparisons:
    - In functions like findIdx, combining multiple logical operators might produce incorrect results due to incorrect handling of && and ||.

```
if (info == mInfo[idx] &&
        ROBIN_HOOD_LIKELY(WKeyEqual::operator()(key,
mKeyVals[idx].getFirst()))) {
        return idx;
    }
```

- Mixed Comparisons:

- Comparing signed and unsigned integers could lead to wrong outcomes, depending on how the system or compiler handles these comparisons.

Category E: Control Flow Issues:

- Potential Infinite Loops:
  - Loops within shiftUp and shiftDown could potentially run indefinitely if the exit conditions are not properly met.
- Unnecessary Loop Iterations:
  - Some loops may execute an extra time or not run at all due to improper initialization or incorrect conditions in the loop headers.

Category F: Interface Issues:

- Mismatched Function Parameter Attributes:
  - Function calls, such as insert_move, may pass parameters that do not match the expected types or sizes.
  - Example: insert_move(std::move(oldKeyVals[i])).
- Global Variable Use:
  - The code uses global variables across functions, which could introduce inconsistencies if they aren't handled properly. This issue isn't directly evident but could become a concern with future code expansions.

Category G: Input/Output Issues:

- Lack of File Handling:
  - Although the current code does not deal with file I/O, future extensions that involve file handling could introduce typical errors such as unclosed files or failing to check end-of-file conditions.

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2. Most Effective Inspection Category:

The Data Reference Issues (Category A) are the most important to focus on due to the use of manual memory management, pointers, and dynamic data structures. Mismanagement of pointers and memory

allocation/deallocation could result in critical problems like crashes, segmentation faults, or memory leaks. In addition to this, Computational Issues and Control Flow Issues are also key areas to inspect, especially in larger, more complex projects.

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3. Considerations for Future Expansion:

- Concurrency Concerns:
    - This review does not address multithreading or concurrency issues, such as race conditions or deadlocks. If the program were to be adapted for concurrent execution, attention would need to be given to handling shared resources, locks, and ensuring thread safety.
- Dynamic Run-Time Issues:
    - Some issues, like memory overflow/underflow or unexpected behavior in specific runtime environments, might not be detected until the program is run in real-world scenarios.

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4. Applicability of Program Inspection Technique:

Yes, this inspection technique is valuable, particularly for catching static issues that may not be flagged by the compiler, such as improper pointer management, array boundary violations, or faulty control flows. While this approach may not reveal all dynamic or concurrency-related errors, it is a crucial process for improving code quality. It is especially useful in memory-sensitive applications like this C++ hash table implementation. By using this method, the reliability of the code is enhanced, and it promotes best practices in areas like memory management, control flow, and logic.

Task II. CODE DEBUGGING: Debugging is the process of localizing, analyzing, and removing suspected errors in the code (Java code given in the .zip file)

Code 1: Armstrong

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - There are two main errors in the code:
        - The calculation of remainder uses integer division, remainder = num / 10;, which gives incorrect results. This line should use modulus (%) to obtain the last digit of the number, i.e., remainder = num % 10;.
        - The calculation of the new value of num in num = num % 10; is incorrect. It should be num = num / 10; to reduce the number by removing the last digit.
2. Which category of program inspection would you find more effective?
    - Code walkthrough or peer review would be more effective for this type of error identification. These methods allow one or more individuals to thoroughly examine the code logic and arithmetic operations used.
3. Which type of error are you not able to identify using the program inspection?
    - Run-time errors or logical issues not easily visible through inspection might be missed. For example, if there were overflow issues or edge case handling problems, these might not be immediately apparent until the program is executed.
4. Is the program inspection technique worth applying?
    - Yes, program inspection can be a useful early-phase debugging technique to catch common syntactic and logical errors before runtime. However, it should be complemented by other testing methods like unit testing and dynamic debugging.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
    - There are two errors in the program:
        - remainder = num / 10; should be remainder = num % 10;.
        - num = num % 10; should be num = num / 10;.
2. How many breakpoints do you need to fix those errors?
   Two breakpoints would be enough to identify and fix both issues:
    - Set a breakpoint before the line where remainder is calculated to inspect how it's dividing instead of taking the modulus.
    - Set another breakpoint before the line where num is being updated to check how it should be reduced.

   Steps to fix the errors:

    - Step 1: Change the line remainder = num / 10; to remainder = num % 10; to get the last digit of the number correctly.
    - Step 2: Modify the line num = num % 10; to num = num / 10; to correctly remove the last digit of the number after extracting the remainder.
3. Submit your complete executable code:

```
// Corrected Armstrong Number Program

class Armstrong {

  public static void main(String args[]) {

    int num = Integer.parseInt(args[0]); // input number

    int n = num; // store the original number for comparison

    int check = 0, remainder;



    while (num > 0) {
```

```
        remainder = num % 10; // get the last digit

        check = check + (int)Math.pow(remainder, 3); // cube the digit and
add to sum

        num = num / 10; // remove the last digit

    }

    if (check == n)

        System.out.println(n + " is an Armstrong Number");

    else

        System.out.println(n + " is not an Armstrong Number");

  }

}
```

Code 2:- GCD and LCM

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - There are two main errors in the code:
        - In the gcd method, the while loop condition is incorrect. It should be while(a % b != 0) instead of while(a % b == 0) because we want to continue until the remainder is zero.
        - In the lcm method, the logic for finding LCM is incorrect. The condition if(a % x != 0 && a % y != 0) should be if(a % x == 0 && a % y == 0) because LCM is the smallest number that is divisible by both x and y.
2. Which category of program inspection would you find more effective?

- Code walkthrough would be effective for identifying these types of errors. Reviewing the logic and conditions carefully can help pinpoint where the calculations and logic deviate from expectations.

3. Which type of error are you not able to identify using the program inspection?
    - Edge cases such as when one of the numbers is zero or when both numbers are the same might not be fully covered using program inspection. These cases would be better caught with test cases and dynamic analysis.
4. Is the program inspection technique worth applying?
    - Yes, program inspection is helpful in catching syntactical and logical errors early, especially simple conditional mistakes like the ones in this program. However, it should be supplemented by actual code
      execution and testing.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
    - Two errors:
        - The while loop condition in gcd should be while(a % b != 0) instead of while(a % b == 0).
        - The condition inside the if statement in lcm should be if(a % x == 0 && a % y == 0) instead of if(a % x != 0 && a % y != 0).
2. How many breakpoints do you need to fix those errors?

   Two breakpoints would be sufficient to fix the errors:

    - One before the while loop in the gcd method to examine the condition.
    - One before the if statement in the lcm method to check the condition for divisibility of a by both x and y.

   Steps to fix the errors:

Step 1: Change while(a % b == 0) to while(a % b != 0) in the gcd method.

Step 2: Modify if(a % x != 0 && a % y != 0) to if(a % x == 0 && a % y == 0) in the lcm method.

3. Submit your complete executable code:

```
import java.util.Scanner;

public class GCD_LCM

{

  static int gcd(int x, int y)

  {

     int r=0, a, b;

     a = (x > y) ? y : x; // a is smaller number

     b = (x < y) ? x : y; // b is greater number

     r = b;

     while(a % b != 0) // Fix: change to != 0

     {

        r = a % b;

        a = b;

        b = r;

     }

     return r;
```

```
}

static int lcm(int x, int y)

{

   int a;

   a = (x > y) ? x : y; // a is greater number

   while(true)

   {

      // Fix: change to == to check divisibility

      if(a % x == 0 && a % y == 0)

         return a;

      ++a;

   }

}

public static void main(String args[])

{

   Scanner input = new Scanner(System.in);

   System.out.println("Enter the two numbers: ");

   int x = input.nextInt();

   int y = input.nextInt();
```

```
        System.out.println("The GCD of two numbers is: " + gcd(x, y));

        System.out.println("The LCM of two numbers is: " + lcm(x, y));

        input.close();

    }
}
```

Code 3:- Knapsack

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: In the line int option1 = opt[n++][w];, the use of n++ is incorrect because it increments n during the iteration, leading to skipping the next item. This should be opt[n-1][w] to refer to the correct value.
    - Error 2: In the condition if (weight[n] > w), this should be if (weight[n] <= w) because we only want to take the item if its weight fits within the current weight limit w.
    - Error 3: In the calculation option2 = profit[n-2] + opt[n-1][w-weight[n]];, the profit term uses n-2 instead of n. This will lead to incorrect profit values. It should be option2 = profit[n] + opt[n-1][w-weight[n]];.
2. Which category of program inspection would you find more effective?
    - Code walkthrough would be effective for catching these logical errors. Systematically reviewing how indices are incremented and how conditions are structured will reveal these issues.
3. Which type of error are you not able to identify using the program inspection?
    - Performance issues and potential edge cases, such as when the weights are zero or when the knapsack is empty, might not be

immediately obvious during inspection. These would be best identified through testing or profiling.

4. Is the program inspection technique worth applying?
    - Yes, program inspection can be helpful for identifying logical flaws, especially around index management and conditions in loops. However, dynamic testing and runtime checks are still necessary to ensure correctness under different input conditions.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: int option1 = opt[n++][w]; should be int option1 = opt[n-1][w].
    - Error 2: if (weight[n] > w) should be if (weight[n] <= w).
    - Error 3: option2 = profit[n-2] + opt[n-1][w-weight[n]]; should be option2 = profit[n] + opt[n-1][w-weight[n]];.
2. How many breakpoints do you need to fix those errors?

    Three breakpoints would be sufficient:

    - One before the line int option1 = opt[n++][w]; to check if n++ is causing unintended skips.
    - One before if (weight[n] > w) to verify the weight condition logic.
    - One before the line option2 = profit[n-2] + opt[n-1][w-weight[n]]; to inspect the correct profit and weight values.

    Steps to fix the errors:

    - Step 1: Change int option1 = opt[n++][w]; to int option1 = opt[n-1][w]; to correctly handle item indexing.
    - Step 2: Modify if (weight[n] > w) to if (weight[n] <= w) to ensure the item is taken when it fits within the current weight.
    - Step 3: Change option2 = profit[n-2] + opt[n-1][w-weight[n]]; to option2 = profit[n] + opt[n-1][w-weight[n]]; to use the correct profit value for the current item.

3. Submit your complete executable code:

```
public class Knapsack {



  public static void main(String[] args) {

     int N = Integer.parseInt(args[0]);   // number of items

     int W = Integer.parseInt(args[1]);   // maximum weight of knapsack



     int[] profit = new int[N+1];

     int[] weight = new int[N+1];



     // generate random instance, items 1..N

     for (int n = 1; n <= N; n++) {

        profit[n] = (int) (Math.random() * 1000);

        weight[n] = (int) (Math.random() * W);

     }



     // opt[n][w] = max profit of packing items 1..n with weight limit w

     // sol[n][w] = does opt solution to pack items 1..n with weight limit w
include item n?
```

```
    int[][] opt = new int[N+1][W+1];
    boolean[][] sol = new boolean[N+1][W+1];


    for (int n = 1; n <= N; n++) {
       for (int w = 1; w <= W; w++) {


          // don't take item n
          int option1 = opt[n-1][w];  // Fix: change n++ to n-1


          // take item n
          int option2 = Integer.MIN_VALUE;
          if (weight[n] <= w)  // Fix: use <= to check if weight fits
             option2 = profit[n] + opt[n-1][w-weight[n]];  // Fix: correct
profit index to profit[n]


          // select better of two options
          opt[n][w] = Math.max(option1, option2);
          sol[n][w] = (option2 > option1);
       }
```

```
    }


    // determine which items to take
    boolean[] take = new boolean[N+1];
    for (int n = N, w = W; n > 0; n--) {
       if (sol[n][w]) {
          take[n] = true;
          w = w - weight[n];
       }
       else {
          take[n] = false;
       }
    }


    // print results
    System.out.println("item" + "\t" + "profit" + "\t" + "weight" + "\t" +
"take");
    for (int n = 1; n <= N; n++) {
```

```
        System.out.println(n + "\t" + profit[n] + "\t" + weight[n] + "\t" +
take[n]);

      }

  }

}
```

Code 4: Magic Number

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: In the inner while loop, the condition while(sum == 0) is incorrect. It should be while(sum > 0) to continue the loop while there are digits to sum.
    - Error 2: The statement s = s * (sum / 10); is incorrect. The correct operation should be s = s + (sum % 10); because we are summing the digits, not multiplying them.
    - Error 3: The line sum = sum % 10 is missing a semicolon (;), leading to a syntax error.
2. Which category of program inspection would you find more effective?
    - Code walkthrough would be more effective for identifying these logical and syntactical errors. Reviewing each part of the loop structure and checking how digits are summed would catch these issues.
3. Which type of error are you not able to identify using the program inspection?
    - Edge cases like negative numbers or very large inputs might not be caught during inspection. These would be better identified using testing with a variety of inputs.
4. Is the program inspection technique worth applying?

- Yes, program inspection helps identify syntax and logic errors early, especially in loops and conditions. However, it should be supplemented by testing with different input cases to ensure full correctness.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
   - Error 1: The inner while(sum == 0) condition should be while(sum > 0) to correctly iterate through the digits.
   - Error 2: The statement s = s * (sum / 10); should be s = s + (sum % 10); to correctly sum the digits.
   - Error 3: The statement sum = sum % 10 is missing a semicolon (;).
2. How many breakpoints do you need to fix those errors?

   Three breakpoints are needed:

   - One before the inner while loop to check the condition.
   - One before the digit summing line to ensure the correct operation is performed.
   - One after the semicolon issue to ensure the loop works properly.

   Steps to fix the errors:

   - Step 1: Change while(sum == 0) to while(sum > 0) to correctly iterate through digits.
   - Step 2: Change s = s * (sum / 10); to s = s + (sum % 10); to properly sum the digits.
   - Step 3: Add the missing semicolon after sum = sum % 10.
3. Submit your complete executable code:

```
import java.util.*;



public class MagicNumberCheck {
```

```
public static void main(String args[]) {

   Scanner ob = new Scanner(System.in);

   System.out.println("Enter the number to be checked.");

   int n = ob.nextInt();

   int sum = 0, num = n;



   // Loop until we reduce the number to a single digit

   while (num > 9) {

      sum = num;

      int s = 0;



      // Fix: Change while condition and summing logic

      while (sum > 0) {

         s = s + (sum % 10);  // Fix: Sum the digits, not multiply

         sum = sum / 10;      // Fix: Divide to get the next digit

      }

      num = s;  // Assign the sum of digits back to num for the next loop

   }
```

```
    // Check if the resulting single digit is 1 (Magic number condition)
    if (num == 1) {
        System.out.println(n + " is a Magic Number.");
    } else {
        System.out.println(n + " is not a Magic Number.");
    }
    ob.close();
  }
}
```

Code 5: Merge Sort

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: The leftHalf and rightHalf methods are passed incorrect parameters in mergeSort. In the line int[] left = leftHalf(array+1); and int[] right = rightHalf(array-1);, the operations array+1 and array-1 are invalid for arrays. They should just pass the array as leftHalf(array) and rightHalf(array).
    - Error 2: In the merge method call within mergeSort, the increment and decrement operations (left++ and right--) are incorrect. Arrays cannot be modified this way. The correct call should be merge(array, left, right);.

2. Which category of program inspection would you find more effective?
    - Code walkthrough would be effective here, as it helps to check each function and how they interact with each other, particularly how arrays are passed and modified in the mergeSort and merge methods.
3. Which type of error are you not able to identify using the program inspection?
    - Performance errors or errors related to handling large input sizes cannot be easily identified using program inspection alone. These would require runtime testing with large datasets to evaluate efficiency and scalability.
4. Is the program inspection technique worth applying?
    - Yes, program inspection is useful to catch logical errors and improper parameter handling. However, thorough testing is necessary to ensure correctness across various cases.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: Incorrect array handling in the calls to leftHalf(array+1) and rightHalf(array-1). Arrays should be passed directly as leftHalf(array) and rightHalf(array).
    - Error 2: Incorrect use of increment and decrement (left++, right--) in the merge call. Arrays should be passed directly as merge(array, left, right).
2. How many breakpoints do you need to fix those errors?

    Two breakpoints are needed:

    - One before the mergeSort method call to check if arrays are passed correctly.
    - One before the merge call to ensure correct merging without modifying array references incorrectly.

    Steps to fix the errors:

- Step 1: Correct the mergeSort calls to pass leftHalf(array) and rightHalf(array) without modifying the array with +1 or -1.
- Step 2: Remove the incorrect increment and decrement operations in the merge method and pass the arrays left and right as they are.

3. Submit your complete executable code:

```
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);  // Fix: Pass array without +1
        int[] right = rightHalf(array); // Fix: Pass array without -1

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

        // merge the sorted halves into a sorted whole
        merge(array, left, right);  // Fix: Pass arrays without ++/--
    }
}

// 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++;

        }

    }

  }

}
```

Code 6: Multiply Matrics

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: In the nested loop responsible for matrix multiplication, the indices used in the line sum = sum + first[c-1][c-k]*second[k-1][k-d]; are incorrect. The indices c-1, c-k, k-1, and k-d do not correctly reference the matrix elements. The correct indices should be first[c][k] * second[k][d].
    - Error 2: The input prompt messages for the second matrix are mistakenly asking for the "rows and columns of the first matrix" again instead of the second matrix.
2. Which category of program inspection would you find more effective?
    - Code review is effective here, where errors in array indexing and logic can be caught by carefully reviewing the matrix multiplication logic.
3. Which type of error are you not able to identify using the program inspection?
    - Boundary errors or errors occurring due to matrix sizes and edge cases (like 1x1 or very large matrices) may not be identified until runtime testing.
4. Is the program inspection technique worth applying?
    - Yes, it is valuable for identifying logical errors in the nested loops and incorrect indexing, which are crucial for matrix operations.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: Incorrect indices used in the matrix multiplication logic: sum = sum + first[c-1][c-k]*second[k-1][k-d];. This causes an ArrayIndexOutOfBoundsException.
    - Error 2: The input prompt message is wrong for the second matrix: "Enter the number of rows and columns of the second matrix" should be used, not the first matrix.
2. How many breakpoints do you need to fix those errors?
   Two breakpoints:

- One before the nested loops start to inspect the indices and ensure the correct matrix elements are being accessed.
- One to check the input message for the second matrix dimensions.

Steps to fix the errors:

- Step 1: Fix the incorrect indices in the matrix multiplication logic. Change sum = sum + first[c-1][c-k]*second[k-1][k-d]; to sum = sum + first[c][k] * second[k][d];.
- Step 2: Correct the input prompt for the second matrix by updating it to "Enter the number of rows and columns of the second matrix."

3. Submit your complete executable code:

```
import java.util.Scanner;



class MatrixMultiplication {

  public static void main(String args[]) {

    int m, n, p, q, sum = 0, c, d, k;



    Scanner in = new Scanner(System.in);

    System.out.println("Enter the number of rows and columns of the first
matrix");

    m = in.nextInt();

    n = in.nextInt();
```

```
    int first[][] = new int[m][n];


    System.out.println("Enter the elements of the first matrix");


    for (c = 0; c < m; c++) {
       for (d = 0; d < n; d++) {
          first[c][d] = in.nextInt();
       }
    }


    System.out.println("Enter the number of rows and columns of the second
matrix");
    p = in.nextInt();
    q = in.nextInt();


    if (n != p) {
       System.out.println("Matrices with entered orders can't be multiplied
with each other.");
```

```
    } else {
        int second[][] = new int[p][q];
        int multiply[][] = new int[m][q];

        System.out.println("Enter the elements of the second matrix");

        for (c = 0; c < p; c++) {
            for (d = 0; d < q; d++) {
                second[c][d] = in.nextInt();
            }
        }

        for (c = 0; c < m; c++) {
            for (d = 0; d < q; d++) {
                for (k = 0; k < n; k++) {
                    sum = sum + first[c][k] * second[k][d];  // Fix: Corrected the indices
                }

                multiply[c][d] = sum;
```

```
            sum = 0;

          }

        }



        System.out.println("Product of entered matrices:-");



        for (c = 0; c < m; c++) {

          for (d = 0; d < q; d++) {

            System.out.print(multiply[c][d] + "\t");

          }

          System.out.print("\n");

        }

    }

  }

}
```

Code 7: Quadratic Probing:

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: In the insert method, the line i + = (i + h / h--) % maxSize; has incorrect syntax. It should be i = (i + h * h++) % maxSize; to properly handle the quadratic probing calculation.
    - Error 2: In the remove method, the rehashing logic decreases the currentSize twice. First during the deletion, and second while re-inserting the keys. This results in incorrect size management.
    - Error 3: There's no initial handling for cases where the hash code might be negative, which can lead to array index out-of-bounds exceptions when performing modulus operations.
    - Error 4: The test inputs suggest entering multiple key-value pairs one after the other, but the current implementation allows only one pair to be inserted per iteration of the loop.
2. Which category of program inspection would you find more effective?
    - Static code analysis is effective in identifying syntax errors, logical errors, and potential edge cases in code (such as handling hash codes and rehashing).
3. Which type of error are you not able to identify using the program inspection?
    - Runtime errors such as hash collisions or handling large inputs may not be immediately identified through static inspection. These errors often surface only during testing or execution.
4. Is the program inspection technique worth applying?
    - Yes, it helps catch both syntax errors and logical flaws that are hard to detect just by executing the program without thorough testing.

Debugging:

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

- Error 1: Syntax error in the insert method on the line i + = (i + h / h--) % maxSize;. This needs to be corrected to i = (i + h * h++) % maxSize;.
- Error 2: Incorrect rehashing and double decrementing of currentSize in the remove method, which needs adjustment.
- Error 3: No handling of negative hash codes, leading to array out-of-bounds errors.
- Error 4: Incomplete test input as the program expects one key-value pair per input, but the prompt suggests multiple key-value pairs.

2. How many breakpoints do you need to fix those errors?
   Three breakpoints:
   - One at the insert method to fix the probing calculation.
   - One at the remove method to handle correct size decrement.
   - One at the hash code calculation to handle negative values.

   Steps to fix the errors:

   - Step 1: Fix the probing calculation in the insert method by correcting i + = (i + h / h--) % maxSize; to i = (i + h * h++) % maxSize;.
   - Step 2: Adjust the remove method to avoid double decrementing the currentSize by only decrementing it once after rehashing.
   - Step 3: Handle negative hash codes by modifying the hash method to return Math.abs(key.hashCode() % maxSize);.
   - Step 4: Modify test inputs in the loop to prompt for one key-value pair at a time.

3. Submit your complete executable code:

```
import java.util.Scanner;



class QuadraticProbingHashTable {

  private int currentSize, maxSize;
```

```
private String[] keys;
private String[] vals;


/** Constructor **/
public QuadraticProbingHashTable(int capacity) {
    currentSize = 0;
    maxSize = capacity;
    keys = new String[maxSize];
    vals = new String[maxSize];
}


/** Function to clear hash table **/
public void makeEmpty() {
    currentSize = 0;
    keys = new String[maxSize];
    vals = new String[maxSize];
}


/** Function to get size of hash table **/
```

```
public int getSize() {
    return currentSize;
}

/** Function to check if hash table is full **/
public boolean isFull() {
    return currentSize == maxSize;
}

/** Function to check if hash table is empty **/
public boolean isEmpty() {
    return getSize() == 0;
}

/** Function to check if hash table contains a key **/
public boolean contains(String key) {
    return get(key) != null;
}
```

```
  /** Function to get hash code of a given key **/
  private int hash(String key) {
     return Math.abs(key.hashCode() % maxSize);  // Fix for handling
negative hash codes
  }


  /** Function to insert key-value pair **/
  public void insert(String key, String val) {
     if (isFull()) {
        System.out.println("Hash Table is full!");
        return;
     }


     int tmp = hash(key);
     int i = tmp, h = 1;


     while (keys[i] != null) {
        if (keys[i].equals(key)) {
           vals[i] = val;  // Replace existing value
```

```
            return;
        }
        i = (i + h * h++) % maxSize;  // Fix: Correct probing
    }

    keys[i] = key;
    vals[i] = val;
    currentSize++;
}

/** Function to get value for a given key **/
public String get(String key) {
    int i = hash(key), h = 1;
    while (keys[i] != null) {
        if (keys[i].equals(key)) {
            return vals[i];
        }
        i = (i + h * h++) % maxSize;
    }
```

```
    return null;
}

/** Function to remove key and its value **/
public void remove(String key) {
    if (!contains(key)) {
        System.out.println("Key not found!");
        return;
    }

    int i = hash(key), h = 1;
    while (!key.equals(keys[i])) {
        i = (i + h * h++) % maxSize;
    }

    keys[i] = vals[i] = null;
    currentSize--;

    // Rehash all keys
```

```
    for (i = (i + h * h++) % maxSize; keys[i] != null; i = (i + h * h++) %
maxSize) {
        String tmpKey = keys[i], tmpVal = vals[i];
        keys[i] = vals[i] = null;
        currentSize--;
        insert(tmpKey, tmpVal);
    }
  }

  /** Function to print HashTable **/
  public void printHashTable() {
    System.out.println("\nHash Table: ");
    for (int i = 0; i < maxSize; i++) {
        if (keys[i] != null) {
            System.out.println(keys[i] + " " + vals[i]);
        }
    }
    System.out.println();
  }
```

```
}


/** Class QuadraticProbingHashTableTest **/

public class QuadraticProbingHashTableTest {

  public static void main(String[] args) {

    Scanner scan = new Scanner(System.in);

    System.out.println("Hash Table Test\n\n");

    System.out.println("Enter size:");


    QuadraticProbingHashTable qpht = new
QuadraticProbingHashTable(scan.nextInt());


    char ch;

    /** Perform QuadraticProbingHashTable operations **/

    do {

      System.out.println("\nHash Table Operations\n");

      System.out.println("1. insert ");

      System.out.println("2. remove");

      System.out.println("3. get");
```

```
        System.out.println("4. clear");
        System.out.println("5. size");


        int choice = scan.nextInt();
        switch (choice) {
           case 1:
              System.out.println("Enter key and value");
              qpht.insert(scan.next(), scan.next());
              break;
           case 2:
              System.out.println("Enter key");
              qpht.remove(scan.next());
              break;
           case 3:
              System.out.println("Enter key");
              System.out.println("Value = " + qpht.get(scan.next()));
              break;
           case 4:
              qpht.makeEmpty();
```

```
                System.out.println("Hash Table Cleared\n");
                break;
            case 5:
                System.out.println("Size = " + qpht.getSize());
                break;
            default:
                System.out.println("Wrong Entry\n");
                break;
        }
        qpht.printHashTable();
        System.out.println("\nDo you want to continue (Type y or n) \n");
        ch = scan.next().charAt(0);
    } while (ch == 'Y' || ch == 'y');
  }
}
```

Code 8: Sorting Array

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: The class name is Ascending _Order with an underscore, which is not a valid identifier in Java. Class names should not have spaces or special characters like underscores.
    - Error 2: The for-loop for sorting has an incorrect condition: for (int i = 0; i >= n; i++);. The loop condition i >= n will prevent the loop from executing since it's checking if i is greater than or equal to n. It should be i < n.
    - Error 3: The loop header for (int i = 0; i >= n; i++); has a semicolon at the end, which will terminate the loop immediately, making it ineffective.
    - Error 4: The condition inside the nested loop is incorrect for sorting in ascending order. The condition if (a[i] <= a[j]) should be if (a[i] > a[j]) to correctly swap the elements when they are out of order.
    - Error 5: The array is printed incorrectly at the end; in the final loop, it should iterate until i < n to print all elements correctly.
2. Which category of program inspection would you find more effective?
    - Static code inspection is most effective here. This would catch syntactic errors like the improper class name, misplaced semicolon in the loop, and incorrect logic for sorting.
3. Which type of error are you not able to identify using the program inspection?
    - Runtime errors or edge cases such as entering negative values or large input sizes might not be caught during static inspection. These would surface during actual execution and testing.
4. Is the program inspection technique worth applying?
    - Yes, program inspection is worth applying. It helps identify logical and syntactical mistakes before running the program and can save significant debugging time.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: The class name Ascending _Order has an invalid identifier.
    - Error 2: The incorrect for-loop condition i >= n.
    - Error 3: The misplaced semicolon in the sorting loop for (int i = 0; i >= n; i++);.
    - Error 4: The incorrect comparison for swapping elements if (a[i] <= a[j]) should be if (a[i] > a[j]).
    - Error 5: The loop to print the array stops too early (i < n - 1).
2. How many breakpoints do you need to fix those errors?

    Five breakpoints:

    - One at the class declaration to correct the class name.
    - One at the outer for-loop to correct the condition and remove the misplaced semicolon.
    - One at the inner for-loop to adjust the comparison for sorting.
    - One for printing the array, correcting the loop condition to iterate over all elements.

    Steps to fix the errors:

    - Step 1: Rename the class from Ascending _Order to AscendingOrder.
    - Step 2: Fix the outer loop condition from i >= n to i < n and remove the semicolon after the loop.
    - Step 3: Fix the comparison inside the inner loop from if (a[i] <= a[j]) to if (a[i] > a[j]) for proper sorting.
    - Step 4: Correct the print loop to iterate over all elements (i < n).
3. Submit your complete executable code:

```
import java.util.Scanner;
```

```
public class AscendingOrder {

  public static void main(String[] args) {

    int n, temp;

    Scanner s = new Scanner(System.in);

    System.out.print("Enter no. of elements you want in array: ");

    n = s.nextInt();

    int a[] = new int[n];

    System.out.println("Enter all the elements:");

    for (int i = 0; i < n; i++) {

      a[i] = s.nextInt();

    }



    // Sorting the array in ascending order

    for (int i = 0; i < n; i++) {  // Corrected loop condition and removed
semicolon

      for (int j = i + 1; j < n; j++) {

        if (a[i] > a[j]) {  // Fixed comparison for ascending order

          temp = a[i];

          a[i] = a[j];
```

```
                a[j] = temp;

            }

        }

    }



    // Printing the sorted array

    System.out.print("Ascending Order: ");

    for (int i = 0; i < n - 1; i++) {

        System.out.print(a[i] + ", ");

    }

    System.out.print(a[n - 1]);  // Print last element without trailing
comma

  }

}
```

Code 9: Stack Implementation

Program Inspection:

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

- Error 1: In the push() method, the operation top-- should be top++. The current implementation decreases the top index instead of increasing it when a new value is pushed onto the stack.
- Error 2: In the display() method, the for-loop condition i > top should be i <= top in order to display all the elements in the stack correctly. The current loop doesn't print the elements properly.
- Error 3: The array indexing for the display() loop also starts from i = 0, which is correct, but the condition and logic of comparing top is wrong.
- Error 4: In the pop() method, the operation top++ is wrong for popping an element. It should be top-- to reduce the index after removing the element.

2. Which category of program inspection would you find more effective?
    - Static code inspection would be the most effective for identifying syntactical and logical errors in this program, especially regarding the management of the top index and loop conditions.
3. Which type of error are you not able to identify using the program inspection?
    - Runtime errors such as stack overflow, underflow, or mismanagement of array bounds might not surface immediately during inspection without test cases. These errors could show up during execution and would be harder to identify using only inspection.
4. Is the program inspection technique worth applying?
    - Yes, it is worth applying. It can catch structural and logical issues related to stack operations before execution, improving the reliability of the code.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: top-- in the push() method should be top++ to correctly increase the index when an element is added.

- Error 2: In the pop() method, the operation top++ should be top-- to reduce the index when removing an element.
- Error 3: The display() method's loop should iterate with i <= top, and it should print all elements in the stack correctly.
- Error 4: In the display() loop, it should print elements as stack[i] with proper boundaries and conditions.

2. How many breakpoints do you need to fix those errors?
   Four breakpoints:
   - One in the push() method to correct top-- to top++.
   - One in the pop() method to correct top++ to top--.
   - One in the display() method to fix the loop condition (i <= top).
   - One in the display() loop to print elements in the correct order.

   Steps to fix the errors:

   - Step 1: Correct the logic in push() to increment top instead of decrementing.
   - Step 2: Fix the pop() method to decrement top correctly.
   - Step 3: Adjust the display() loop condition to iterate over the valid range of the stack.
   - Step 4: Ensure the array elements are printed correctly in the display() method.
3. Submit your complete executable code:

```
import java.util.Scanner;



public class StackMethods {

  private int top;

  int size;

  int[] stack;
```

```
public StackMethods(int arraySize) {
    size = arraySize;
    stack = new int[size];
    top = -1;
}

public void push(int value) {
    if (top == size - 1) {
        System.out.println("Stack is full, can't push a value");
    } else {
        top++;  // Corrected: Incrementing top to add new value
        stack[top] = value;
    }
}

public void pop() {
    if (!isEmpty()) {
        top--;  // Corrected: Decrementing top to remove value
```

```
    } else {
        System.out.println("Can't pop...stack is empty");
    }
}

public boolean isEmpty() {
    return top == -1;
}

public void display() {
    if (isEmpty()) {
        System.out.println("Stack is empty");
        return;
    }

    for (int i = 0; i <= top; i++) {  // Corrected: Loop to display elements properly
        System.out.print(stack[i] + " ");
    }
```

```
        System.out.println();
    }
}


public class StackReviseDemo {
    public static void main(String[] args) {
        StackMethods newStack = new StackMethods(5);
        newStack.push(10);
        newStack.push(1);
        newStack.push(50);
        newStack.push(20);
        newStack.push(90);


        newStack.display();


        newStack.pop();
        newStack.pop();
        newStack.pop();
        newStack.display();
```

```
  }

}
```

Code 10: Tower of Hanoi

Program Inspection:

1. How many errors are there in the program? Mention the errors you have identified.
    - Error 1: In the recursive call doTowers(topN ++, inter--, from+1, to+1), the increment (++) and decrement (--) operators on the method parameters are incorrect. The parameters should remain unchanged throughout the recursive calls. The correct call should be doTowers(topN - 1, inter, from, to).
    - Error 2: The characters (char) from+1, to+1, and inter-- are incorrect, as arithmetic operations on characters are not meaningful in this context. The characters represent the rods, so no such operations should be applied.
    - Error 3: Missing semicolon after the doTowers recursive call in the else block: doTowers(topN ++, inter--, from+1, to+1).
2. Which category of program inspection would you find more effective?
    - Static code inspection is useful for catching syntax errors (like the missing semicolon) and logical errors, such as the incorrect use of increment and arithmetic operations on characters.
3. Which type of error are you not able to identify using the program inspection?
    - Logical runtime errors related to stack overflow or incorrect recursion depth would not be easily identified through static inspection without actual testing or tracing through execution.
4. Is the program inspection technique worth applying?

- Yes, it can catch errors early in the code review phase, especially for simple syntactical mistakes and logical errors in recursive functions like this one.

Debugging:

1. How many errors are there in the program? Mention the errors you have identified.
   - Error 1: Incorrect increment (++) and decrement (--) of parameters in recursive call.
   - Error 2: Invalid character arithmetic (from+1, to+1, inter--).
   - Error 3: Missing semicolon in the recursive call.
2. How many breakpoints do you need to fix those errors?
   Three breakpoints:
   - One to fix the recursive call by removing the incorrect arithmetic on parameters.
   - One to remove the increment and decrement operations on the parameters.
   - One to add the missing semicolon.

   Steps to fix the errors:

   - Step 1: Remove ++ and -- from doTowers(topN ++, inter--, from+1, to+1) and replace it with the correct parameters for recursion.
   - Step 2: Remove invalid arithmetic on from+1, to+1, and inter--.
   - Step 3: Add the missing semicolon after the recursive method call.
3. Submit your complete executable code:

```
public class MainClass {

 public static void main(String[] args) {

   int nDisks = 3;

   doTowers(nDisks, 'A', 'B', 'C');
```

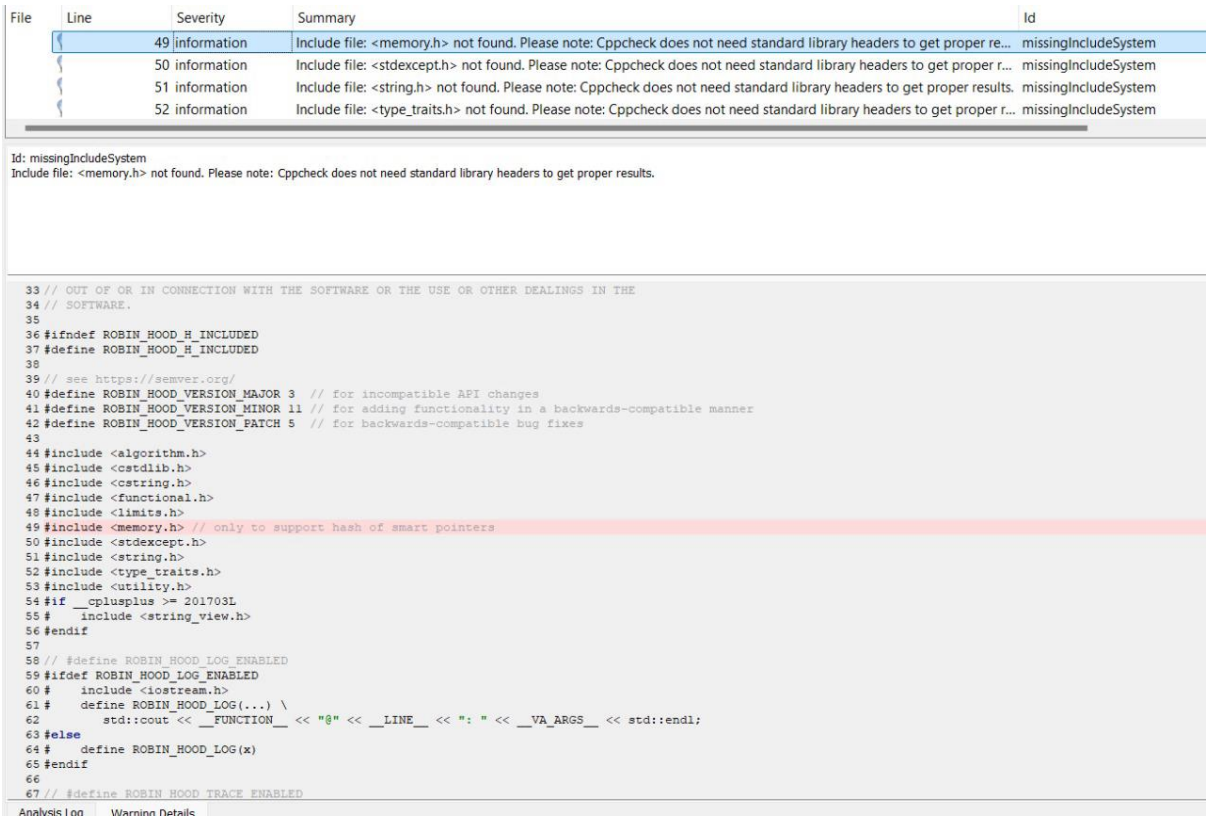
```
}


public static void doTowers(int topN, char from, char inter, char to) {
  if (topN == 1) {
    System.out.println("Disk 1 from " + from + " to " + to);
  } else {
    // Move top n-1 disks from 'from' to 'inter' using 'to' as auxiliary
    doTowers(topN - 1, from, to, inter);

    // Move nth disk from 'from' to 'to'
    System.out.println("Disk " + topN + " from " + from + " to " + to);

    // Move top n-1 disks from 'inter' to 'to' using 'from' as auxiliary
    doTowers(topN - 1, inter, from, to);  // Corrected recursion
  }
 }
}
```

Task III. STATIC ANALYSIS TOOLS

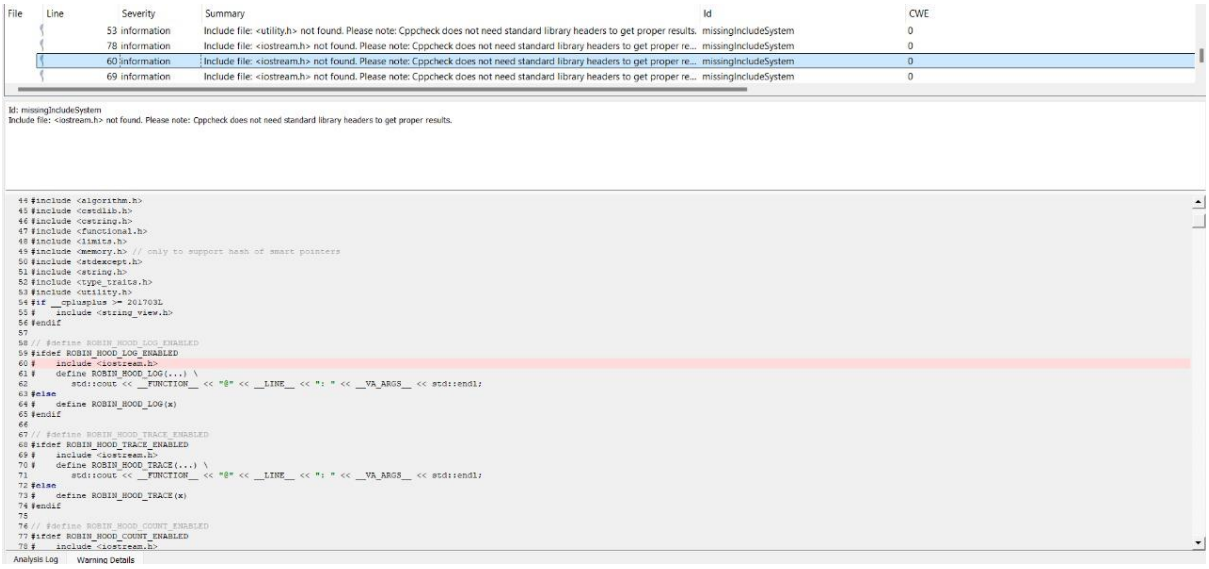


File	Line	Severity	Summary	Id
	49	information	Include file: <memory.h> not found. Please note: Cppcheck does not need standard library headers to get proper re...	missingIncludeSystem
	50	information	Include file: <stdexcept.h> not found. Please note: Cppcheck does not need standard library headers to get proper r...	missingIncludeSystem
	51	information	Include file: <string.h> not found. Please note: Cppcheck does not need standard library headers to get proper results.	missingIncludeSystem
	52	information	Include file: <type_traits.h> not found. Please note: Cppcheck does not need standard library headers to get proper r...	missingIncludeSystem

Id: missingIncludeSystem
Include file: <memory.h> not found. Please note: Cppcheck does not need standard library headers to get proper results.

```
33 // OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE
34 // SOFTWARE.
35
36 #ifndef ROBIN_HOOD_H_INCLUDED
37 #define ROBIN_HOOD_H_INCLUDED
38
39 // see https://semver.org/
40 #define ROBIN_HOOD_VERSION_MAJOR 3  // for incompatible API changes
41 #define ROBIN_HOOD_VERSION_MINOR 11 // for adding functionality in a backwards-compatible manner
42 #define ROBIN_HOOD_VERSION_PATCH 5  // for backwards-compatible bug fixes
43
44 #include <algorithm.h>
45 #include <cstdlib.h>
46 #include <cstring.h>
47 #include <functional.h>
48 #include <limits.h>
49 #include <memory.h> // only to support hash of smart pointers
50 #include <stdexcept.h>
51 #include <string.h>
52 #include <type_traits.h>
53 #include <utility.h>
54 #if __cplusplus >= 201703L
55 #    include <string_view.h>
56 #endif
57
58 // #define ROBIN_HOOD_LOG_ENABLED
59 #ifdef ROBIN_HOOD_LOG_ENABLED
60 #    include <iostream.h>
61 #    define ROBIN_HOOD_LOG(...) \
62         std::cout << __FUNCTION__ << "@" << __LINE__ << ": " << __VA_ARGS__ << std::endl;
63 #else
64 #    define ROBIN_HOOD_LOG(x)
65 #endif
66
67 // #define ROBIN_HOOD_TRACE_ENABLED
```

Analysis Log | Warning Details



File	Line	Severity	Summary	Id	CWE
	53	information	Include file: <utility.h> not found. Please note: Cppcheck does not need standard library headers to get proper results.	missingIncludeSystem	0
	78	information	Include file: <iostream.h> not found. Please note: Cppcheck does not need standard library headers to get proper re...	missingIncludeSystem	0
	60	information	Include file: <iostream.h> not found. Please note: Cppcheck does not need standard library headers to get proper re...	missingIncludeSystem	0
	69	information	Include file: <iostream.h> not found. Please note: Cppcheck does not need standard library headers to get proper re...	missingIncludeSystem	0

Id: missingIncludeSystem
Include file: <iostream.h> not found. Please note: Cppcheck does not need standard library headers to get proper results.

```
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47 #include <functional.h>
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49 #include <memory.h> // only to support hash of smart pointers
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53 #include <utility.h>
54 #if __cplusplus >= 201703L
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56 #endif
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65 #endif
66
67 // #define ROBIN_HOOD_TRACE_ENABLED
68 #ifdef ROBIN_HOOD_TRACE_ENABLED
69 #    include <iostream.h>
70 #    define ROBIN_HOOD_TRACE(...) \
71         std::cout << __FUNCTION__ << "@" << __LINE__ << ": " << __VA_ARGS__ << std::endl;
72 #else
73 #    define ROBIN_HOOD_TRACE(x)
74 #endif
75
76 // #define ROBIN_HOOD_COUNT_ENABLED
77 #ifdef ROBIN_HOOD_COUNT_ENABLED
78 #    include <iostream.h>
```
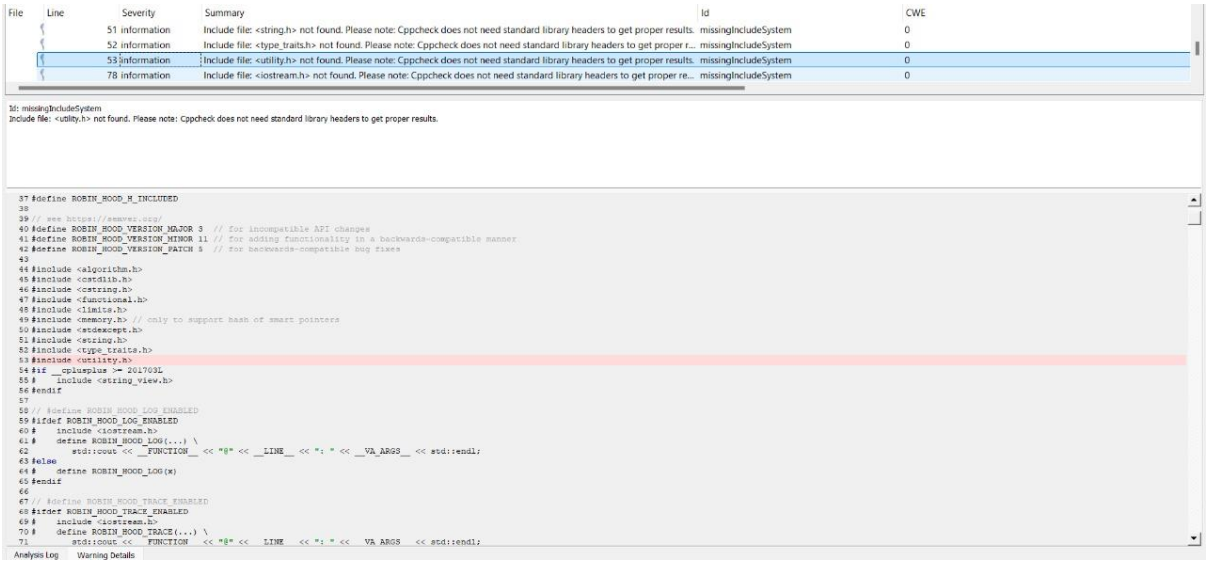

Analysis Log | Warning Details


File Line Severity Summary Id CWE
51 information Include file: <string.h> not found. Please note: Cppcheck does not need standard library headers to get proper results. missingIncludeSystem 0
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62 std::cout << __FUNCTION__ << "@" << __LINE__ << ": " << __VA_ARGS__ << std::endl;
63 #else
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65 #endif
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67 // #define ROBIN_HOOD_TRACE_ENABLED
68 #ifdef ROBIN_HOOD_TRACE_ENABLED
69 # include <iostream.h>
70 # define ROBIN_HOOD_TRACE(...) \
71 std::cout << __FUNCTION__ << "@" << __LINE__ << ": " << __VA_ARGS__ << std::endl;
Analysis Log
Warning Details

Thank You