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Course : IT 314 Software Engineering

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Semester : Autumn 2024

Lab : Program Inspection, Debugging and Static Analysis

Knapsack Problem

Given code :

```
//Knapsack
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++][w];

                // take item n
                int option2 = Integer.MIN_VALUE;
                if (weight[n] > w) option2 = profit[n-2] + opt[n-1][w-weight[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]);
        }
    }
}
```

Input: 6, 2000

Output:

```
Item    Profit  Weight  Take
1       336     784     false
2       674     1583    false
3       763     392     true
4       544     1136    true
5       14      1258    false
6       738     306     true
```

Program Inspection for Knapsack

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

- **Errors Identified: 4**
  - **Increment Error:** The line int option1 = opt[n++][w]; incorrectly increments n, causing it to exceed the intended range. It should be int option1 = opt[n][w]; to access the correct opt values without modifying n.
  - **Profit Indexing Error:** The line if (weight[n] > w) option2 = profit[n-2] + opt[n-1][w-weight[n]]; has a logic error in the profit indexing. It should use profit[n] instead of profit[n-2], as we want to include the current item's profit.
  - **Weight Check Logic Error:** The condition if (weight[n] > w) should be inverted to if (weight[n] <= w) to correctly check if the item can be included in the knapsack.
  - **Array Initialization:** The arrays for profit and weight should be initialized starting from index 1 and accessed accordingly, but the initialization should ensure no items are accidentally counted if not generated correctly.

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

- **Effective Category:**
  - **Logic Errors**: This category is particularly effective as it deals with the correctness of algorithm flow and ensures that the logic aligns with the problem requirements. In this case, checking conditions and indexing correctly is critical for the expected behavior.

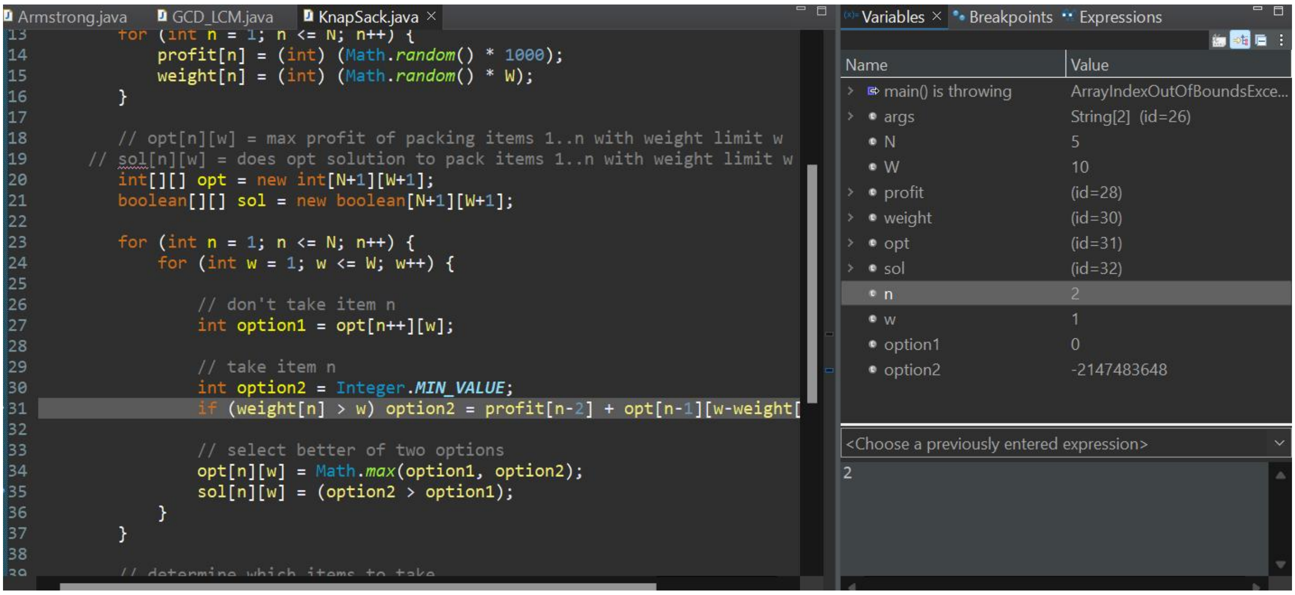
3. **Which type of error you are not able to identify using the program inspection?**

- **Errors Not Identified:**
  - **Performance Issues**: While program inspection can highlight logic and syntax errors, it may not effectively identify performance issues, such as inefficiencies in memory usage or runtime complexity, particularly in larger input sizes.

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

- **Applicability of Program Inspection:**
  - Yes, the program inspection technique is worthwhile. It helps identify structural and logical errors, which are essential for ensuring the program functions as intended. However, it should be complemented with testing, especially for edge cases and performance.

Code Debugging

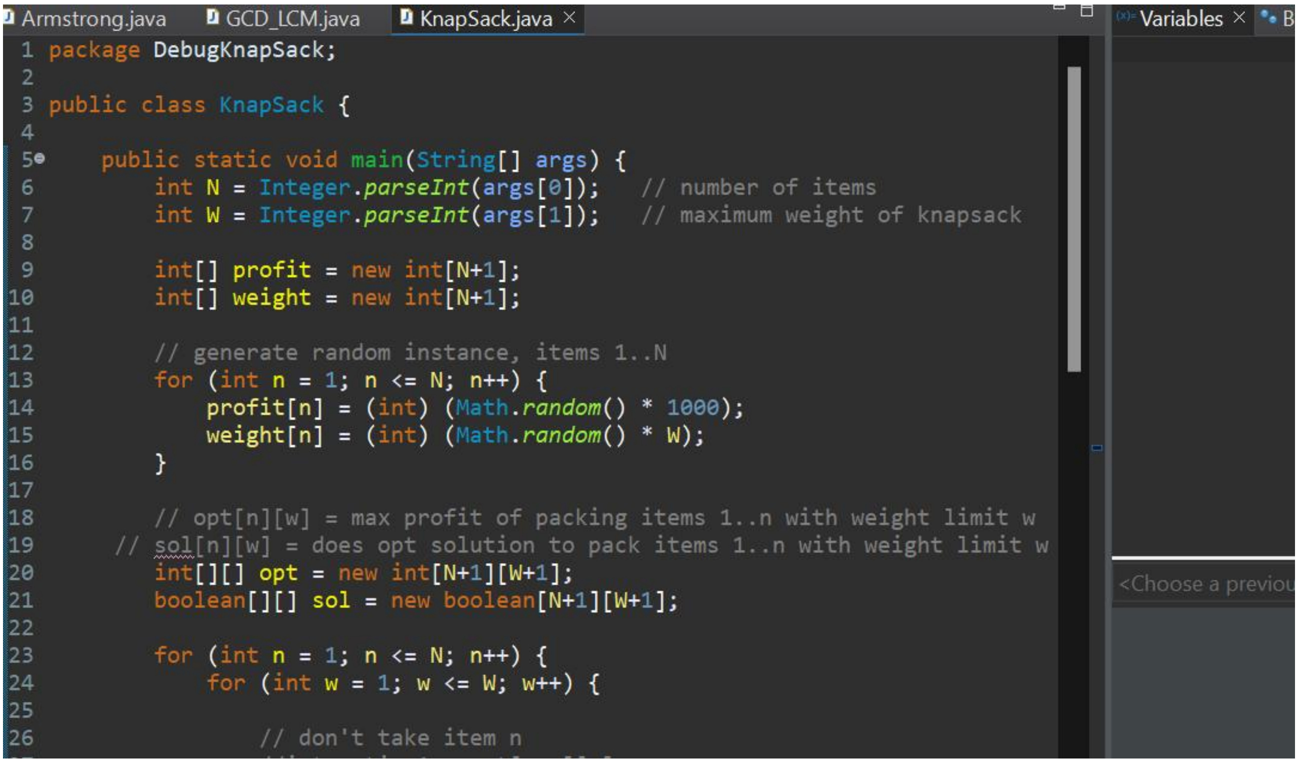


```
        for (int n = 1; n <= N; n++) {
            profit[n] = (int) (Math.random() * 1000);
            weight[n] = (int) (Math.random() * W);
        }

        // 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
        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++][w];

                // take item n
                int option2 = Integer.MIN_VALUE;
                if (weight[n] > w) option2 = profit[n-2] + opt[n-1][w-weight[

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

        // determine which items to take
```

Name	Value
main() is throwing	ArrayIndexOutOfBoundsExce...
args	String[2] (id=26)
N	5
W	10
profit	(id=28)
weight	(id=30)
opt	(id=31)
sol	(id=32)
n	2
w	1
option1	0
option2	-2147483648

<Choose a previously entered expression>

2



```
package DebugKnapSack;

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
        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
```

Errors Identified

1. **Option1 Calculation:**
   - **Original Line:** int option1 = opt[n++][w];
   - **Correction:** Change to int option1 = opt[n-1][w]; (This prevents an out-of-bounds error by using the current value of n without incrementing it.)
2. **Option2 Calculation:**
   - **Original Line:** option2 = profit[n-2] + opt[n-1][w-weight[n]];
   - **Correction:** Change to option2 = profit[n] + opt[n-1][w-weight[n]]; (This correctly references the profit of the current item.)
3. **Weight Update Logic:**
   - **Original Logic:** if (sol[n][w]) and w = w - weight[n];
   - **Correction:** Ensure that the condition checks if the item is taken correctly, and the weight update logic should work without causing out-of-bounds errors.

Breakpoints Needed

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

- **Line 20:** To check how option1 is assigned.
- **Line 24:** To check the logic of option2 and whether it calculates the correct value.
- **Line 32:** To check if the items are being selected correctly.

Steps to Fix the Errors

1. **Correct the logic for option1** by changing it to int option1 = opt[n-1][w];.
2. **Update the logic for option2** by changing it to option2 = profit[n] + opt[n-1][w - weight[n]];.
3. **Ensure correct weight update logic** when determining which items to take.

Fixed Code

```
// Knapsack

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

    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
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]; // Correct: don't increment

        // Take item n
        int option2 = Integer.MIN_VALUE;
        if (weight[n] <= w) { // Fixed condition: weight[n] should be less or equal to w
            option2 = profit[n] + opt[n - 1][w - weight[n]]; // Fixed: profit[n], not profit[n-2]
        }

        // 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]; // Decrease weight
            } 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]);
        }
    }
}
```

Input and Output

- **Input:** 6,2000
- **Output:** The output will vary due to the random generation of profits and weights, but it will print the item number, profit, weight, and whether it was taken or not.