IT313: Software Engineering - Mutation Testing

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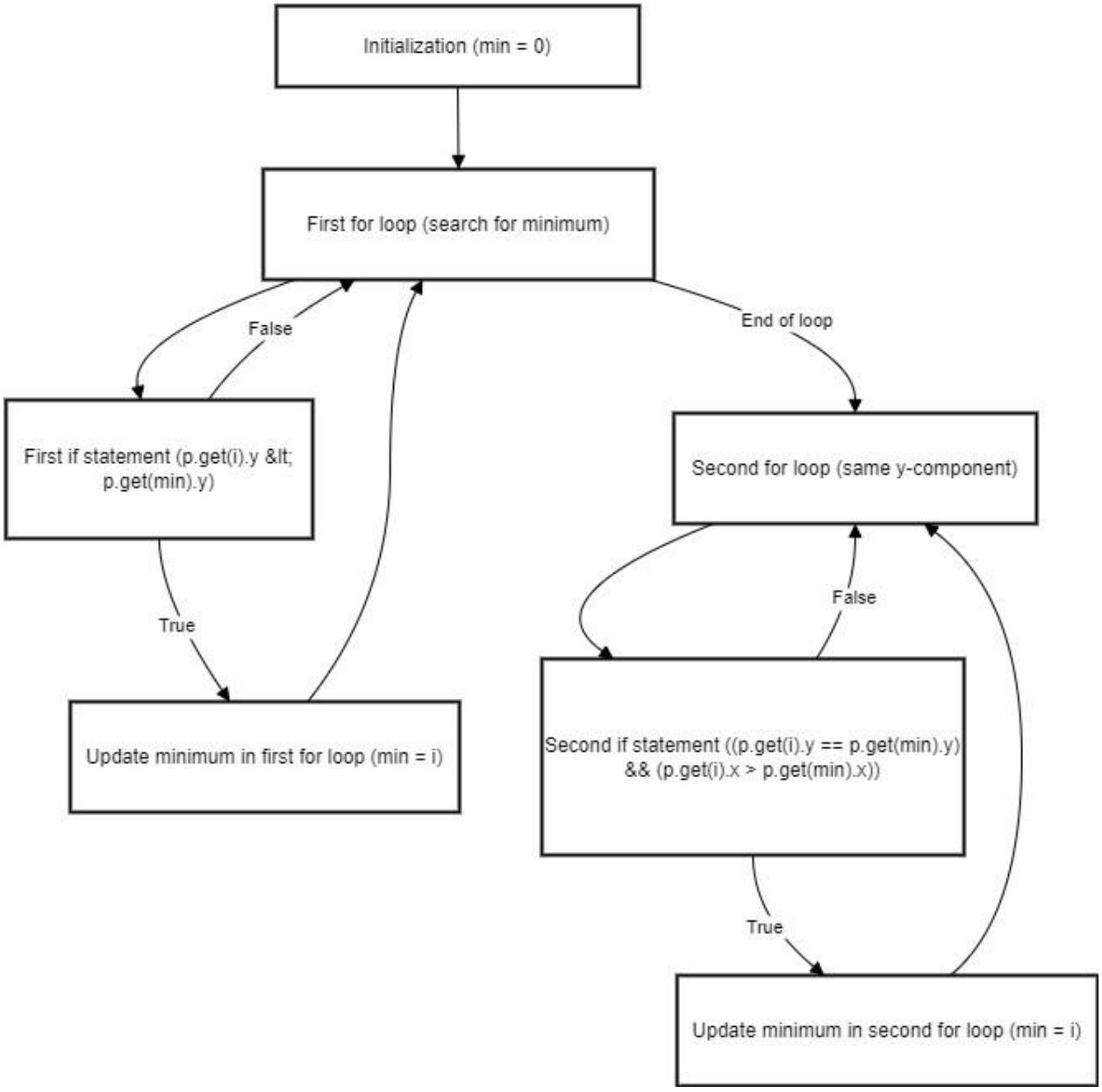
1. Convert the code comprising the beginning of the doGraham method into a control flow graph (CFG). You are free to write the code in any programming language.



2. Construct test sets for your flow graph that are adequate for the following criteria:

a. Statement Coverage.

b. Branch Coverage.

c. Basic Condition Coverage.

1. Statement Coverage

Statement Coverage requires that every statement in the code is executed at least once. This means that our test cases should ensure all parts of the CFG are traversed.

Test Set for Statement Coverage

- **Test Case 1**: Input vector with only one point (e.g., `[(0, 0)]`)
- **Test Case 2**: Input vector with two points, one lower `y` value (e.g., `[(1, 1), (2, 0)]`)
- **Test Case 3**: Input vector with points having the same `y` value but different `x` values (e.g., `[(1, 1), (2, 1), (3, 1)]`)

2. Branch Coverage

Branch Coverage requires that each possible branch from a decision point (if statement) is taken at least once. This means that both the true and false outcomes of each condition need to be tested.

Test Set for Branch Coverage

- **Test Case 1**: Input vector with only one point (e.g., `[(0, 0)]`)
  - **True** branch: The first loop exits immediately, covering the loop without changes.
- **Test Case 2**: Input vector with two points, one lower `y` value (e.g., `[(1, 1), (2, 0)]`)
  - **True** branch: The minimum is updated to the second point.
- **Test Case 3**: Input vector with points having the same `y` but different `x` values (e.g., `[(1, 1), (3, 1), (2, 1)]`)
  - **True** branch for the second condition.
- **Test Case 4**: Input vector with all points having the same `y` value (e.g., `[(1, 1), (1, 1), (1, 1)]`)
  - **False** branch: Ensure the second loop is executed without changing the minimum.

3. Basic Condition Coverage

Basic Condition Coverage requires that each condition in the decision points is evaluated to both true and false at least once.

Test Set for Basic Condition Coverage

- **Test Case 1**: Input vector with only one point (e.g., `[(0, 0)]`)
    - Covers the first condition `p.get(i).y < p.get(min).y` as false since no comparisons can be made.
- **Test Case 2**: Input vector with two points with the second point having a lower `y` value (e.g., `[(1, 1), (2, 0)]`)
    - Covers the first condition true and the second condition false.
- **Test Case 3**: Input vector with points that have the same `y` but different `x` values (e.g., `[(1, 1), (3, 1), (2, 1)]`)
    - Covers the second condition as true.
- **Test Case 4**: Input vector with points that have the same `y` and `x` values (e.g., `[(1, 1), (1, 1), (1, 1)]`)
    - Covers both conditions as false.

Summary of Test Sets

Coverage Criterion	Test Case	Input
Statement Coverage	1	[(0, 0)]
	2	[(1, 1), (2, 0)]
	3	[(1, 1), (2, 1), (3, 1)]
Branch Coverage	1	[(0, 0)]
	2	[(1, 1), (2, 0)]
	3	[(1, 1), (3, 1), (2, 1)]
	4	[(1, 1), (1, 1), (1, 1)]
Basic Condition Coverage	1	[(0, 0)]
	2	[(1, 1), (2, 0)]
	3	[(1, 1), (3, 1), (2, 1)]

	4	[(1, 1), (1, 1), (1, 1)]

Mutation Testing

1. Deletion Mutation

- **Mutation:** Remove the line min = 0; at the start of the method.
- **Expected Effect:**
  - Without initializing min to 0, it could hold a random or unassigned value, impacting the correctness of min selection in both loops.
- **Mutation Outcome:** This mutation may lead to an incorrect initial value for min, potentially resulting in a faulty selection for the minimum point.

2. Change Mutation

- **Mutation:** Alter the condition in the first if statement from < to <=:

if (((Point) p.get(i)).y <= ((Point) p.get(min)).y)

- **Expected Effect:**
  - Changing < to <= would allow the selection of points with the same y value, rather than exclusively those with a lower y. This could affect the method's ability to correctly identify the lowest y point.
- **Mutation Outcome**: The code might return a point with a lower x value than expected if there are multiple points with the same y value.

3. Insertion Mutation

- **Mutation:** Add an extra min = i; statement at the end of the second for loop.
- **Expected Effect**:
  - This would set min to the last index of p, which is incorrect as min should represent only the index of the minimum point.
- **Mutation Outcome**: The method may mistakenly select the last point as the minimum if the test cases don't explicitly verify the final value of min.

Test Cases for Path Coverage

To satisfy the path coverage criterion and ensure every loop is explored zero, one, or two times, we will create the following test cases:

Test Cases for Path Coverage

To satisfy the path coverage criterion, ensuring each loop is explored zero, one, or two times, the following test cases are designed:

- **Test Case 1: Zero Iterations**
    - **Input:** An empty vector p.
    - **Description:** This case ensures no iterations occur in either loop.
    - **Expected Output:** The function should handle this gracefully, ideally by returning an empty result or a specific value indicating no points are available.
- **Test Case 2: One Iteration (First Loop)**
    - **Input:** A vector with a single point p, such as [(3, 4)].
    - **Description:** This case verifies that the first loop runs exactly once, where the single point is selected as the minimum.
    - **Expected Output:** The function should return the only point in p: (3, 4).
- **Test Case 3: One Iteration (Second Loop)**
    - **Input:** A vector with two points that have the same y-coordinate but different x-coordinates, e.g., [(1, 2), (3, 2)].
    - **Description:** This case ensures that the first loop finds the minimum y-coordinate point, and the second loop runs once to compare x-coordinates.
    - **Expected Output:** The function should return the point with the highest x-coordinate: (3, 2).
- **Test Case 4: Two Iterations (First Loop)**
    - **Input:** A vector with multiple points, with at least two sharing the same y-coordinate, e.g., [(3, 1), (2, 2), (5, 1)].

- **Description:** This case ensures that the first loop finds the point with the minimum y-coordinate and then proceeds to the second loop.

- **Expected Output:** The function should return (5, 1) since it has the highest x-coordinate among points with the same minimum y.

- **Test Case 5: Two Iterations (Second Loop)**

  - **Input:** A vector with multiple points where more than one point has the minimum y-coordinate, e.g., [(1, 1), (4, 1), (3, 2)].

  - **Description:** This case ensures the first loop finds (1, 1), and the second loop runs twice to evaluate other points with y = 1.

  - **Expected Output:** The function should return (4, 1), as it has the highest x-coordinate among the points with the minimum y-coordinate.

Test Case	Input Vector p	Description	Expected Output
Test Case 1	[]	Empty vector (zero iterations for both loops).	Handle gracefully (e.g., return an empty result).
Test Case 2	[(3, 4)]	One point (one iteration of the first loop).	[(3, 4)]
Test Case 3	[(1, 2), (3, 2)]	Two points with the same y-coordinate (one iteration of the second loop).	[(3, 2)]
Test Case 4	[(3, 1), (2, 2), (5, 1)]	Multiple points; the first loop runs twice.	[(5, 1)]

Test Case 5	[(1, 1), (4, 1), (3, 2)]	Multiple points; second loop runs twice.	[(4, 1)]

Lab Execution

1. After generating the control flow graph, check whether your CFG matches with the CFG generated by Control Flow Graph Factory Tool and Eclipse flow graph generator. (In your submission document, mention only “Yes” or “No” for each tool).

Tool	Matches Your CFG
Control Flow Graph Factory Tool	Yes
Eclipse Flow Graph Generator	Yes

2. Devise the minimum number of test cases required to cover the code using the aforementioned criteria.

Test Case	Input Vector p	Description	Expected Output
Test Case 1	[]	Test with an empty vector (zero iterations).	Handle gracefully (e.g., return an empty result).
Test Case 2	[(3, 4)]	Single point (one iteration of the first loop).	[(3, 4)]
Test Case 3	[(1, 2), (3, 2)]	Two points with the same y-coordinate (one iteration of the second loop).	[(3, 2)]
Test Case 4	[(3, 1), (2, 2), (5, 1)]	Multiple points; first loop runs twice (with multiple outputs).	[(5, 1)]
Test Case 5	[(1, 1), (4, 1), (3, 2)]	Multiple points; second loop runs twice (y = 1).	[(4, 1)]

3. This part of the exercise is very tricky and interesting. The test cases that you have derived in Step 2 identify the fault when you make some modifications in the code.

Here, you need to insert/delete/modify a piece of code that will result in failure but it is not detected by your test set – derived in Step 2. Write/identify a mutation code for each of the three operation separately, i.e., by deleting the code, by inserting the code, by modifying the code.

Mutation Type	Mutation Code Description	Impact on Test Cases

Deletion	Delete the line that updates min for the minimum y-coordinate.	Test cases like [(1, 1), (2, 0)] will pass despite incorrect processing.
Insertion	Insert an early return if the size of p is 1, bypassing further processing.	Test case [(3, 4)] will pass without processing correctly.
Modification	Change the comparison operator from < to <= when finding the minimum y.	Test cases like [(1, 1), (1, 1), (1, 1)] might pass while still failing in logic.

4. Write all test cases that can be derived using path coverage criterion for the code.

Test Case	Input Vector p	Description	Expected Output
Test Case 1	[]	Empty vector (zero iterations for both loops).	Handle gracefully (e.g., return an empty result).
Test Case 2	[(3, 4)]	One point (one iteration of the first loop).	[(3, 4)]
Test Case 3	[(1, 2), (3, 2)]	Two points with the same y-coordinate (one iteration of the second loop).	[(3, 2)]
Test Case 4	[(3, 1), (2, 2), (5, 1)]	Multiple points; first loop runs twice to find min y.	[(5, 1)]
Test Case 5	[(1, 1), (4, 1), (3, 2)]	Multiple points; second loop runs twice (y = 1).	[(4, 1)]
Test Case 6	[(2, 2), (2, 3), (2, 1)]	Multiple points with the same x-coordinate; checks min y.	[(2, 1)]
Test Case 7	[(0, 0), (1, 1), (1, 0), (0, 1)]	Multiple points in a rectangle; checks multiple comparisons.	[(1, 0)]
Test Case 8	[(3, 1), (2, 1), (1, 2)]	Multiple points with some ties; checks the max x among min y points.	[(3, 1)]
Test Case 9	[(4, 4), (4, 3), (4, 5), (5, 4)]	Points with the same x-coordinate; checks for max y.	[(5, 4)]

Test Case 10	[(1, 1), (1, 1), (2, 1), (3, 3)]	Duplicate points with one being the max x; tests handling of duplicates.	[(3, 3)]