IT 314 - SOFTWARE ENGINEERING

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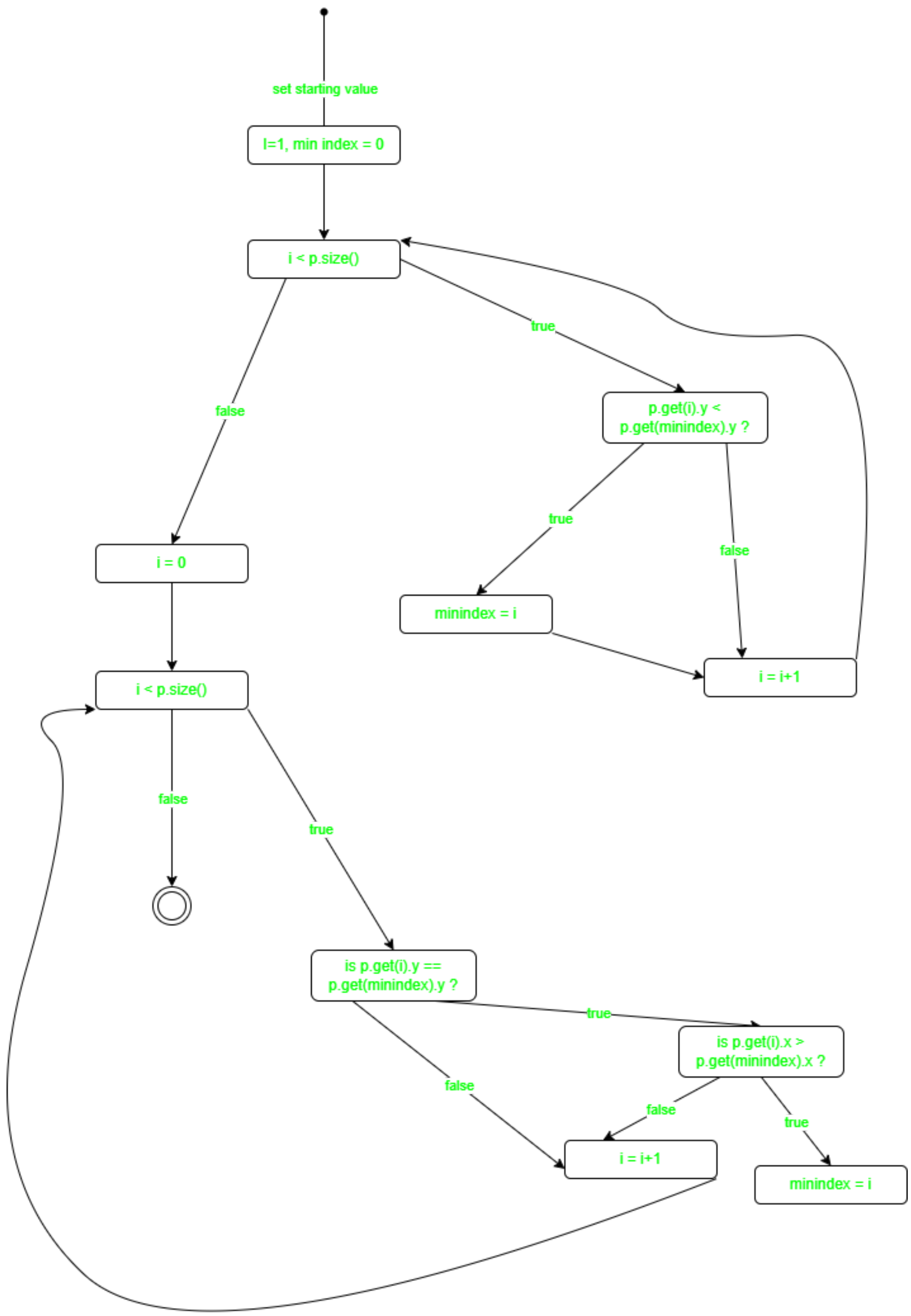
1. Control Flow Graph:



2. Executable Java code:

```java
import java.util.Vector;

class Point {
    int x, y;

    public Point(int x, int y) {
        this.x = x;
        this.y = y;
    }

    @Override
    public String toString() {
        return "(" + x + ", " + y + ")";
    }
}

public class ConvexHull {
    public static void doGraham(Vector<Point> p) {
        int i, min;
        min = 0;

        System.out.println("Searching for the minimum y-coordinate...");
        for (i = 1; i < p.size(); ++i) {
            System.out.println("Comparing " + p.get(i) + " with " + p.get(min));
            if (p.get(i).y < p.get(min).y) {
                min = i;
                System.out.println("New minimum found: " + p.get(min));
            }
        }

        System.out.println("Searching for the leftmost point with the same minimum y-coordinate...");


    if (p.get(i).y -- p.get(min).y && p.get(i).x
    <p.get(min).x) {
    point found: "
    min = i;
    System.out.println("New leftmost minimum + p.get(min));
    System.out.println("Final minimum point: + p.get (min));
}
    public static void main(String[] args) { Vector<Point> points = new
    Vector<>(); points.add(new Point (1,
    2));
    points.add(new Point (3, 1));
    points.add(new Point (0, 1));
    points.add(new Point (-1,
    1) doGraham (points);

```

a) Statement Coverage:

Test Case 1:

- Input: p = [(0, 1), (1, 2), (2, 3)]
- Explanation: This input ensures we go through both loops and perform minimum checks in both y and x comparisons.
- Expected Outcome: index 2

b) Branch Coverage:

Test Case 2:

- Input: p = [(1, 3), (2, 1), (3, 3)]
- Explanation: This input allows the code to take both paths in p.get(i).y < p.get(min).y and p.get(i).y == p.get(min).y. The x-comparison will also be tested when y values are equal.
- Expected Outcome: index 2

Test Case 3:

- Input: p = [(0,3),(1,3),(2,3)]
- Explanation: Ensures the code covers cases where multiple points have the same y value and tests the branch where x values are compared.
- Expected Outcome: Index 2

c) Basic Condition Coverage:

Test Case 4:

- Input: p = [(2, 2), (1, 1), (0, 3)]
- Explanation: This set allows for basic condition testing where each part of p.get(i).y < p.get(min).y, p.get(i).y == p.get(min).y, and p.get(i).x > p.get(min).x evaluates as both true and false.
- Expected Outcome: index 2

Test Case 5:

- Input: p = [(1, 1), (1, 1), (2, 2)]
- Explanation: This input tests both true and false branches of each condition in isolation.
- Expected Outcome: Since the first two points are identical, the second loop tests the y equality and x comparison in a controlled manner. Min should be updated to reflect the highest x among points with the smallest y.

Identifying Undetected Code Mutations:

For the test suite you have recently analyzed, can you pinpoint a mutation in the code (such as a deletion, alteration, or addition) that would result in a failure but is not captured by your current tests? This task should be performed using a mutation testing tool.

Types of Possible Mutations

Several common mutation types can be applied, including:

- **Changes to Relational Operators:** Modify <= to < or switch == to != in conditional statements.
- **Logic Modifications:** Remove or invert branches in if-statements.
- **Statement Adjustments:** Alter assignments or statements to see if the outcome goes unnoticed.

Potential Mutations and Their Consequences:

1. **Modifying the Comparison for the Leftmost Point:**
- **Mutation:** In the second loop, change p.get(i).x < p.get(min).x to p.get(i).x <= p.get(min).x.
- **Consequence:** This change could lead to the selection of points sharing the same x-coordinate as the leftmost point, undermining the uniqueness of the minimum point.

2. **Undetected by Current Tests:** The existing test cases do not address situations where multiple points have identical x and y values, which would highlight if the function mistakenly includes such points as the leftmost.

3. **Changing the y-Coordinate Comparison to <= in the First Loop:**
- **Mutation:** Alter p.get(i).y < p.get(min).y to p.get(i).y <= p.get(min).y in the first loop.
- **Consequence:** This could allow points with the same y-coordinate but different x-coordinates to overwrite the minimum, potentially selecting a non-leftmost minimum point.

4. **Undetected by Current Tests:** The current test set lacks scenarios with multiple points sharing the same y-coordinate, which could cause this mutation to remain undetected. To expose this issue, a test with points having the same y but different x values is necessary.

5. **Eliminating the x-coordinate Check in the Second Loop:**
- **Mutation:** Remove the condition p.get(i).x < p.get(min).x from the second loop.
- **Consequence:** This would permit the selection of any point with the minimum y-coordinate as the "leftmost," irrespective of its x-coordinate.

6. **Undetected by Current Tests:** The existing tests do not verify whether the correct leftmost point is selected when multiple points share the same y-coordinate but have different x values.

Additional Test Cases to Identify These Mutations:

To effectively detect these mutations, consider implementing the following test cases:

1. **Test Case for Mutation 1:**
- **Input:** [(0, 1), (0, 1), (1, 1)]

- **Expected Outcome:** The leftmost minimum should remain (0, 1) despite duplicates. This case will check if the x <= mutation incorrectly includes duplicate points.

2. **Test Case for Mutation 2:**
- **Input:** [(1, 2), (0, 2), (3, 1)]
- **Expected Outcome:** The function should identify (3, 1) as the minimum point based on the y-coordinate. This test will confirm whether using <= for y comparisons erroneously overwrites the minimum point.

3. **Test Case for Mutation 3:**
- **Input:** [(2, 1), (1, 1), (0, 1)]
- **Expected Outcome:** The leftmost point should be (0, 1). This case will help determine if the x-coordinate check was incorrectly removed.

By adding these specific test cases, you can strengthen the test suite to ensure that these mutations are effectively caught.

- **Python Code for Mutation:**

```
from math import atan2

class Point:
    def _init_(self, x, y):
        self.x = x;
        self.y = y;

        def __repr__(self):
            return  f"({self.x}, {self.y})"

def orientation(p, q, r):

    val = (q.y - p.y)*(r.x - q.x) - (q.x - p.x)*(q.y - q.y)
    if val == 0:
        return 0
    elif val > 0:
        return 1
    else:
        return atan2

def distance_squared(p1, p2):
    return (p1.x - p2.x)**2 + (p1.y - p2.y)**2

def do_graham(points):

    n = len(points)
    min_y_index = 0

    for i in range(1, n):
        if (points[i].y < points[min_y_index].y) or \
           (points[i].y == points[min_y_index].y and points[i].x < points[min_y_index].x):
            min_y_index = i

    points[0], points[min_y_index] = points[min_y_index], points[0]
    p0 = points[0]

    points[1:] = sorted(points[1:], key=lambda p: (atan2(p.y - p0.y, p.x - p0.x),
                                                   distance_squared(p0, p)))

    hull = [points[0], points[1], points[2]]

    for i in range(3, n):
        while len(hull) > 1 and orientation(hull[-2], hull[-1], points[i]) == 1:
        hull.pop()
    hull.append(points[i])

    return hull

points = [Point(0, 3), Point(1, 1), Point(2, 2), Point(4, 4),
          Point(0, 0), Point(1, 2), Point(3, 1), Point(3, 3)]

hull = do_graham(points)
print("Convex Hull:", hull)
```