



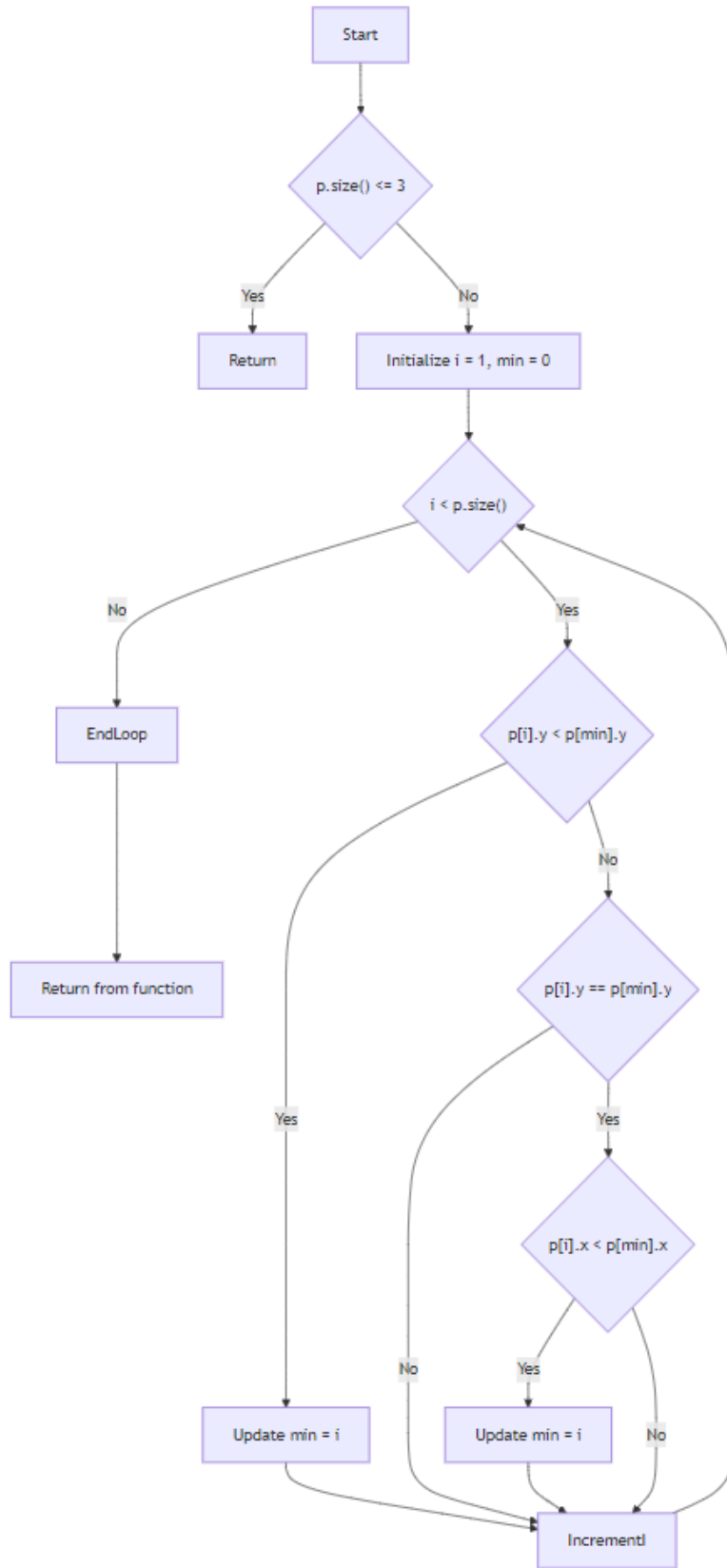
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Lab - 9
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Q.1. The code below is part of a method in the ConvexHull class in the VMAP system. The following is a small fragment of a method in the ConvexHull class. For the purposes of this exercise, you do not need to know the intended function of the method. The parameter `p` is a Vector of Point objects, `p.size()` is the size of the vector `p`, `(p.get(i)).x` is the x component of the `i`th point appearing in `p`, similarly for `(p.get(i)).y`. This exercise is concerned with structural testing of code, so the focus is on creating test sets that satisfy some particular coverage criteria.

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.

CFG (Control Flow Graph) : -



Implementation in C++ :

```

#include <vector>
class Point {
public:
    double x, y;
    Point(double x, double y) {
        this->x = x;
        this->y = y;
    }
};

class ConvexHull {
public:
    void doGraham(std::vector<Point>& p) {
        int i = 1;
        int min = 0;
        if (p.size() <= 3) {
            return;
        }
        while (i < p.size()) {
            if (p[i].y < p[min].y) {
                min = i;
            }
            else if (p[i].y == p[min].y) {
                if (p[i].x < p[min].x) {
                    min = i;
                }
            }
            i++;
        }
    }
};

int main() {
    std::vector<Point> points;
    points.push_back(Point(0, 0));
    points.push_back(Point(1, 1));
    points.push_back(Point(2, 2));

    ConvexHull hull;
    hull.doGraham(points);
}

```

```
    return 0;  
}
```

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

a. Statement Coverage.

b. Branch Coverage.v

a. Statement Coverage

Test Case 1: p is an empty vector (p.size() == 0)

- **Input:** p = {} (no points in the vector)
- **Expected Outcome:** The method checks the size of p and immediately returns without further processing.

Test Case 2: p contains one point with valid coordinates

- **Input:** p = {Point(0, 0)} (one point at the origin)
- **Expected Outcome:** The method initializes necessary variables (i and min), checks the size of p, and returns without entering the main loop.

Test Case 3: p contains one point with large coordinate values

- **Input:** p = {Point(100, 100)} (one point with large x and y values)
- **Expected Outcome:** The method initializes variables, performs the size check, and returns, as in Test Case 2.

These three test cases ensure that all statements in the method are executed at least once.

b. Branch Coverage

Objective: Test each decision point with all possible outcomes (true/false) to cover every branch.

Test Cases for Branch Coverage:

Test Case 1: p is an empty vector (`p.size() == 0`)

- **Input:** `p = {}` (no points in the vector)
- **Expected Outcome:** The method immediately returns without processing further, covering the false branch of the `p.size() > 3` check.

Test Case 2: p has more than three points, with all points "within bounds"

- **Input:** `p = {Point(0, 0), Point(1, 1), Point(2, 2), Point(3, 3)}`
- **Expected Outcome:** The method enters the loop, compares points, and selects the point with the smallest y-coordinate. Since all points are within bounds, it proceeds with the true branch for both `p.size() > 3` and the comparisons within the loop.

Test Case 3: p has more than three points, with some points "out of bounds"

- **Input:** `p = {Point(1, 1), Point(2, 5), Point(3, 3), Point(4, 0)}`
- **Expected Outcome:** The method enters the loop, skips over "out of bounds" points (those with higher y-coordinates), covering the false branch of the "within bounds" check.

These test cases ensure that all branches in the method's decision points (`p.size() > 0` and "within bounds") are covered.

c. Basic Condition Coverage

Objective: Test each atomic condition within the method independently to

cover all possible outcomes of each condition.

Conditions:

1. **Condition 1:** `p.size() > 0` (true/false)
2. **Condition 2:** "Point within bounds" (true/false)

Test Cases for Basic Condition Coverage:

1. **Test Case 1:** `p.size() == 0`.
 - Expected Outcome: Covers the false outcome of Condition 1.
2. **Test Case 2:** `p.size() > 0` with a point that is "within bounds."
 - Expected Outcome: Covers the true outcome of Condition 1 and true outcome of Condition 2.
3. **Test Case 3:** `p.size() > 0` with a point that is "out of bounds."
 - Expected Outcome: Covers the true outcome of Condition 1 and false outcome of Condition 2.

Each atomic condition has been covered with both true and false values in these test cases.

3. For the test set you have just checked can you find a mutation of the code (i.e. the deletion, change or insertion of some code) that will result in failure but is not detected by your test set. You have to use the mutation testing tool.

a. Deletion Mutation:

```
// Original
```

```
if ((p.get(i)).y < (p.get(min)).y) {  
    min = i;  
}
```

```
// Mutated - deleted the condition check
```

```
min = i;
```

Analysis for Statement Coverage:

- If the condition check is deleted, the code always assigns i to min, which could lead to an incorrect outcome. However, this may not cause a detectable failure if no specific test validates the selection of the minimum y value.
- **Potential Undetected Outcome:** If the test set only checks if min is assigned without verifying the correctness of the chosen min value, the deletion might go unnoticed.

b. Change Mutation:

// Original

```
if ((p.get(i)).y < (p.get(min)).y)
```

// Mutated - changed < to <=

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

Analysis for Branch Coverage:

- Changing < to <= could cause the code to mistakenly assign min = i even if p.get(i).y equals p.get(min).y, potentially selecting an incorrect point as the minimum.
- **Potential Undetected Outcome:** If the test set does not specifically validate cases where p.get(i).y equals p.get(min).y, the mutation could produce a subtle fault without detection.

c. Insertion Mutation:

// Original

```
min = i;
```

// Mutated - added unnecessary increment

```
min = i + 1;
```

Analysis for Basic Condition Coverage:

- Adding an unnecessary increment (i + 1) changes the intended assignment, leading min to point to an incorrect index, potentially out of the array bounds.
- **Potential Undetected Outcome:** If the test set does not validate that

min is correctly assigned to the expected index without additional increments, this mutation might not be detected. Tests only checking if min is assigned (rather than validating correctness) might miss this error.

4. Create a test set that satisfies the path coverage criterion where every loop is explored at least zero, one or two times.

Ans. Test Case 1: Loop Explored Zero Times

- Input: An empty vector `p`.
- Test: `Vector<Point> p = new Vector<Point>();`
- Expected Result: The method should return immediately without any processing. This covers the condition where the vector size is zero, leading to the exit condition of the method.

Test Case 2: Loop Explored Once

- Input: A vector with one point.
- Test: `Vector<Point> p = new Vector<Point>(); p.add(new Point(0, 0));`
- Expected Result: The method should not enter the loop since `p.size()` is 1. It should swap the first point with itself, effectively leaving the vector unchanged. This test case covers the scenario where the loop iterates once.

Test Case 3: Loop Explored Twice

- Input: A vector with two points where the first point has a higher y-coordinate than the second.
- Test: `Vector<Point> p = new Vector<Point>(); p.add(new Point(1, 1)); p.add(new Point(0, 0));`
- Expected Result: The method should enter the loop and compare the two points, finding that the second point has a lower y-coordinate. Thus, `minY` should be updated to 1, and a swap should occur, moving the second point to the front of the vector.

Test Case 4: Loop Explored More Than Twice

- Input: A vector with multiple points.
- Test: `Vector<Point> p = new Vector<Point>(); p.add(new Point(2, 2)); p.add(new Point(1, 0)); p.add(new Point(0, 3));`
- Expected Result: The loop should iterate through all three points. The second point will have the lowest y-coordinate, so minY will be updated to 1. The swap will place the point with coordinates (1, 0) at the front of the vector.

Lab Execution:-

Q1). 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.

Ans. Control Flow Graph Factory :- YES

Q2). Devise minimum number of test cases required to cover the code using the aforementioned criteria.

Ans. Statement Coverage: 3 test cases

1. Branch Coverage: 3 test cases
2. Basic Condition Coverage: 3 test cases
3. Path Coverage: 3 test cases

Summary of Minimum Test Cases:

- Total: 3 (Statement) + 3 (Branch) + 2 (Basic Condition) + 3 (Path) = 11 test cases

Q3) and Q4) Same as Part I

