IT-314 Lab 9

Mutation Testing

Harsh Popatiya
202201463

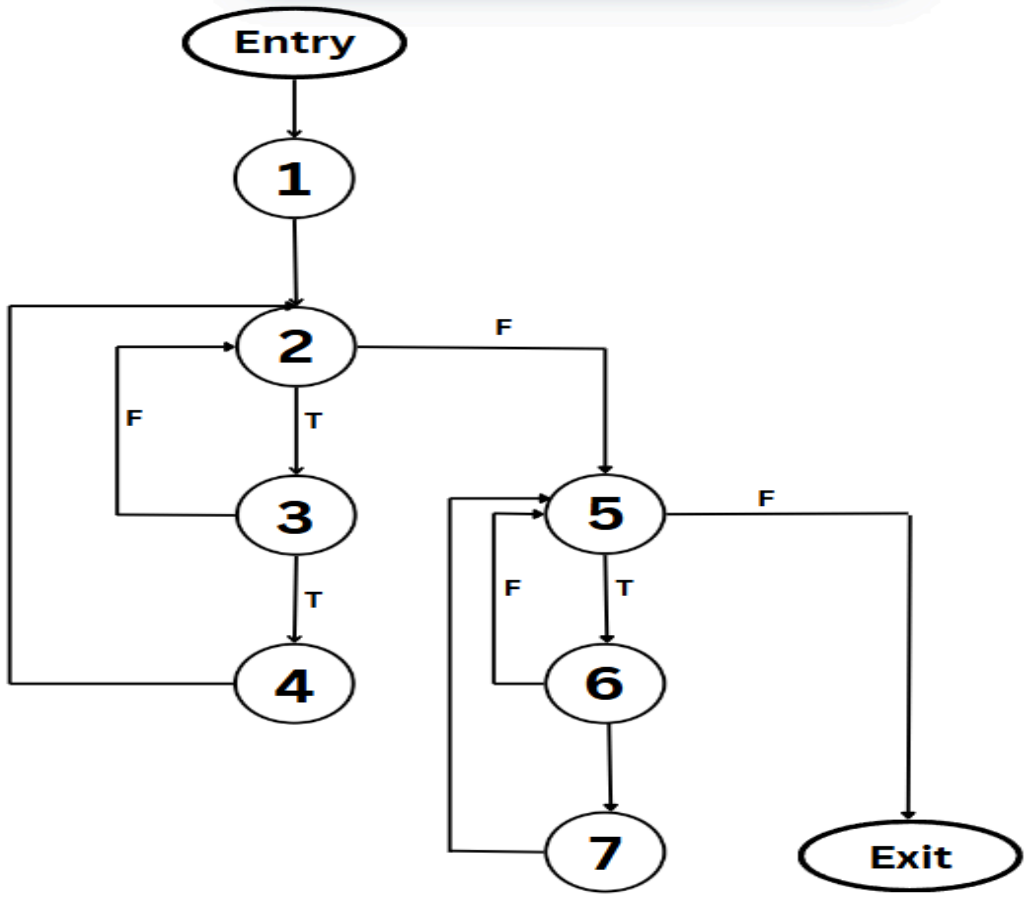
1. **Convert the code comprising the beginning of the doGraham method into a control flow graph (CFG).**

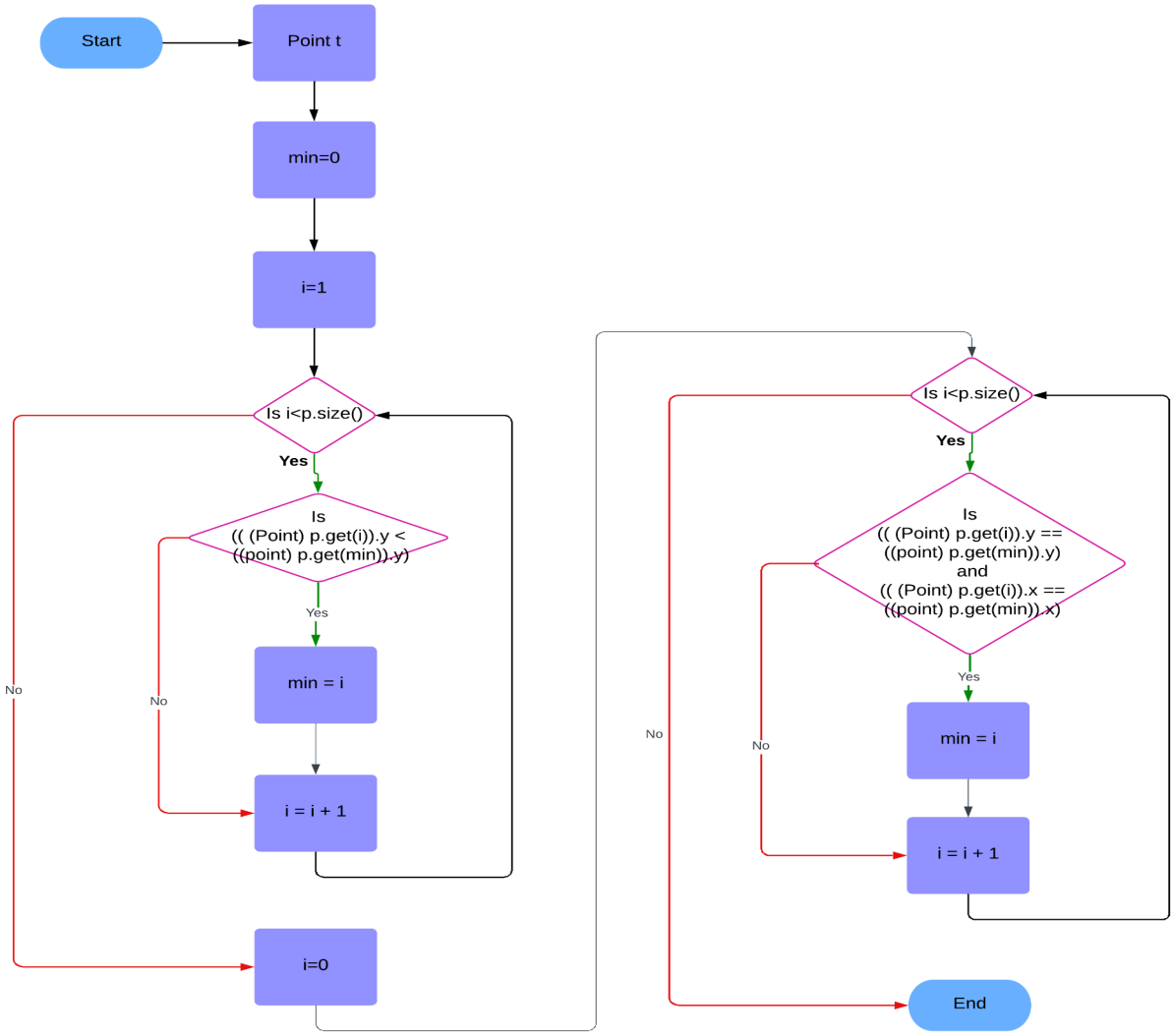
```
Vector doGraham(Vector p) {
        int i,j,min,M;

   1  |  Point t;
      |  min = 0;

        // search for minimum:
   2  |  for(i=1; i < p.size(); ++i) {
   3  |       if( ((Point) p.get(i)).y <
      |                   ((Point) p.get(min)).y )
      |       {
   4  |           min = i;
      |       }
        }

        // continue along the values with same y component
   5  |  for(i=0; i < p.size(); ++i) {
      |       if(( ((Point) p.get(i)).y ==
   6  |                   ((Point) p.get(min)).y ) &&
      |            (((Point) p.get(i)).x >
      |                   ((Point) p.get(min)).x ))
      |       {
   7  |           min = i;
      |       }
        }
```




Start
Point t
min=0
i=1
Is i<p.size()
Yes
Is
(((Point) p.get(i)).y <
((point) p.get(min)).y)
Yes
min = i
i = i + 1
No
No
i=0
Is i<p.size()
Yes
Is
(((Point) p.get(i)).y ==
((point) p.get(min)).y)
and
(((Point) p.get(i)).x ==
((point) p.get(min)).x)
Yes
min = i
i = i + 1
No
No
End

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

Statement Coverage

Statement coverage requires that each statement in the code is executed at least once. This ensures that all lines (1 to 7 in the code) are covered in at least one of the test cases.

Test Set for Statement Coverage:

- **Test Case 1: Single Point**
  - **Input:** `points = [Point(0, 0)]`
  - **Expected Result:** `min_index = 0`
  - **Path:** Entry → 1 → 2 (False) → 5 → 6 (False) → Exit
- **Test Case 2: Multiple Points with Unique Minimum y-Coordinate**
  - **Input:** `points = [Point(1, 3), Point(2, 2), Point(0, 1)]`
  - **Expected Result:** `min_index = 2`
  - **Path:** Entry → 1 → 2 (True) → 3 (True) → 4 → 2 (False) → 5 → 6 (False) → Exit

b. Branch Coverage

Branch coverage requires that each branch in the code (True/False paths for each decision) is taken at least once.

Test Set for Branch Coverage:

- **Test Case 1: Single Point**
  - **Input:** `points = [Point(0, 0)]`
  - **Expected Result:** `min_index = 0`
  - **Path:** Entry → 1 → 2 (False) → 5 → 6 (False) → Exit
- **Test Case 2: Multiple Points with Unique Minimum y-Coordinate**
  - **Input:** `points = [Point(0, 3), Point(1, 2), Point(2, 1)]`
  - **Expected Result:** `min_index = 2`
  - **Path:** Entry → 1 → 2 (True) → 3 (True) → 4 → 2 (False) → 5 → 6 (False) → Exit
- **Test Case 3: Tied Minimum y-Coordinate with Different x-Coordinates**
  - **Input:** `points = [Point(0, 1), Point(2, 1), Point(1, 3)]`
  - **Expected Result:** `min_index = 1`
  - **Path:** Entry → 1 → 2 (True) → 3 (False) → 2 (False) → 5 → 6 (True) → 7 → 5 → 6 (False) → Exit

This test set achieves branch coverage by ensuring that each branch (True/False paths for both loops and conditions) is taken.

c. Basic Condition Coverage

Basic Condition Coverage requires that each individual condition within every decision is evaluated as both True and False at least once.

Test Set for Basic Condition Coverage:

- **Test Case 1: Single Point (ensures `points[i].y < points[min_index].y` is False)**
  - **Input:** `points = [Point(0, 0)]`
  - **Expected Result:** `min_index = 0`
  - **Path:** Entry → 1 → 2 (False) → 5 → 6 (False) → Exit
- **Test Case 2: Unique Minimum y-Coordinate (ensures `points[i].y < points[min_index].y` is True)**
  - **Input:** `points = [Point(0, 3), Point(1, 2), Point(2, 1)]`
  - **Expected Result:** `min_index = 2`
  - **Path:** Entry → 1 → 2 (True) → 3 (True) → 4 → 2 (False) → 5 → 6 (False) → Exit
- **Test Case 3: Tied Minimum y-Coordinate with Larger x (ensures `points[i].y == points[min_index].y` is True, and `points[i].x > points[min_index].x` is True)**
  - **Input:** `points = [Point(0, 1), Point(2, 1)]`
  - **Expected Result:** `min_index = 1`
  - **Path:** Entry → 1 → 2 (True) → 3 (False) → 2 (False) → 5 → 6 (True) → 7 → Exit
- **Test Case 4: Tied Minimum y-Coordinate with Smaller x (ensures `points[i].y == points[min_index].y` is True, and `points[i].x > points[min_index].x` is False)**
  - **Input:** `points = [Point(2, 1), Point(0, 1)]`
  - **Expected Result:** `min_index = 0` (point with the smallest x-coordinate is selected)
  - **Path:** Entry → 1 → 2 (True) → 3 (False) → 2 (False) → 5 → 6 (True) → Exit

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.**

```
[*] Start mutation process:
   - targets: point
   - tests: test_points
[*] 4 tests passed:
   - test_points [0.36220 s]
[*] Start mutants generation and execution:
   - [#   1] COI point:
--------------------------------------------------------------------------------
   6:
   7: def find_min_point(points):
   8:     min_index = 0
   9:     for i in range(1, len(points)):
- 10:         if points[i].y < points[min_index].y:
+ 10:         if not (points[i].y < points[min_index].y):
  11:             min_index = i
  12:     for i in range(len(points)):
  13:         if (points[i].y == points[min_index].y and points[i].x > points[min_index].x):
  14:             min_index = i
--------------------------------------------------------------------------------
[0.23355 s] killed by test_points.py::TestFindMinPoint::test_multiple_points_with_ties
   - [#   2] COI point:
--------------------------------------------------------------------------------
```

```
--------------------------------------------------------------------------------
[0.23355 s] killed by test_points.py::TestFindMinPoint::test_multiple_points_with_ties
   - [#   2] COI point:
--------------------------------------------------------------------------------
   9:     for i in range(1, len(points)):
  10:         if points[i].y < points[min_index].y:
  11:             min_index = i
  12:     for i in range(len(points)):
- 13:         if (points[i].y == points[min_index].y and points[i].x > points[min_index].x):
+ 13:         if not ((points[i].y == points[min_index].y and points[i].x > points[min_index].x)):
  14:             min_index = i
  15:     return points[min_index]
--------------------------------------------------------------------------------
[0.27441 s] killed by test_points.py::TestFindMinPoint::test_multiple_points_with_same_y
   - [#   3] LCR point:
--------------------------------------------------------------------------------
   9:     for i in range(1, len(points)):
  10:         if points[i].y < points[min_index].y:
  11:             min_index = i
  12:     for i in range(len(points)):
- 13:         if (points[i].y == points[min_index].y and points[i].x > points[min_index].x):
+ 13:         if (points[i].y == points[min_index].y or points[i].x > points[min_index].x):
  14:             min_index = i
  15:     return points[min_index]
```

```
--------------------------------------------------------------------------------
[0.18323 s] survived
   - [#   6] ROR point:
--------------------------------------------------------------------------------
   9:     for i in range(1, len(points)):
  10:         if points[i].y < points[min_index].y:
  11:             min_index = i
  12:     for i in range(len(points)):
- 13:         if (points[i].y == points[min_index].y and points[i].x > points[min_index].x):
+ 13:         if (points[i].y != points[min_index].y and points[i].x > points[min_index].x):
  14:             min_index = i
  15:     return points[min_index]
--------------------------------------------------------------------------------
[0.18059 s] killed by test_points.py::TestFindMinPoint::test_multiple_points_with_same_y
   - [#   7] ROR point:
--------------------------------------------------------------------------------
   9:     for i in range(1, len(points)):
  10:         if points[i].y < points[min_index].y:
  11:             min_index = i
  12:     for i in range(len(points)):
- 13:         if (points[i].y == points[min_index].y and points[i].x > points[min_index].x):
+ 13:         if (points[i].y == points[min_index].y and points[i].x < points[min_index].x):
  14:             min_index = i
  15:     return points[min_index]
--------------------------------------------------------------------------------
```

```
[0.13933 s] killed by test_points.py::TestFindMinPoint::test_multiple_points_with_same_y
   - [#   8] ROR point:
--------------------------------------------------------------------------------
   9:     for i in range(1, len(points)):
  10:         if points[i].y < points[min_index].y:
  11:             min_index = i
  12:     for i in range(len(points)):
- 13:         if (points[i].y == points[min_index].y and points[i].x > points[min_index].x):
+ 13:         if (points[i].y == points[min_index].y and points[i].x >= points[min_index].x):
  14:             min_index = i
  15:     return points[min_index]
--------------------------------------------------------------------------------
[0.11494 s] survived
[*] Mutation score [2.22089 s]: 75.0%
   - all: 8
   - killed: 6 (75.0%)
   - survived: 2 (25.0%)
   - incompetent: 0 (0.0%)
   - timeout: 0 (0.0%)
```

```
[0.12519 s] survived
[*] Mutation score [1.53947 s]: 75.0%
   - all: 8
   - killed: 6 (75.0%)
   - survived: 2 (25.0%)
   - incompetent: 0 (0.0%)
   - timeout: 0 (0.0%)
```

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

```python
import unittest

from point import Point, find_min_point

class TestFindMinPointPathCoverage(unittest.TestCase):

    def test_no_points(self):

        points = []

        with self.assertRaises(IndexError):  # Expect an IndexError due to empty list

            find_min_point(points)

    def test_single_point(self):

        points = [Point(0, 0)]

        result = find_min_point(points)

        self.assertEqual(result, points[0])  # Expect the point (0, 0)

    def test_two_points_unique_min(self):

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

        result = find_min_point(points)

        self.assertEqual(result, points[0])  # Expect the point (1, 2)
```

```
    def test_multiple_points_unique_min(self):
        points = [Point(1, 4), Point(2, 3), Point(0, 1)]
        result = find_min_point(points)
        self.assertEqual(result, points[2])  # Expect the point (0, 1)
    def test_multiple_points_same_y(self):
        points = [Point(1, 2), Point(3, 2), Point(2, 2)]
        result = find_min_point(points)
        self.assertEqual(result, points[1])  # Expect the point (3, 2)
    def test_multiple_points_minimum_y_ties(self):
        points = [Point(1, 2), Point(2, 2), Point(3, 1), Point(4, 1)]
        result = find_min_point(points)
        self.assertEqual(result, points[3])  # Expect the point (4, 1)
# Run the tests if this file is executed
if __name__ == "__main__":
    unittest.main()
```

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).**
    - **Yes**