IT314 - Software Engineering
Lab - 9
Mutation Testing

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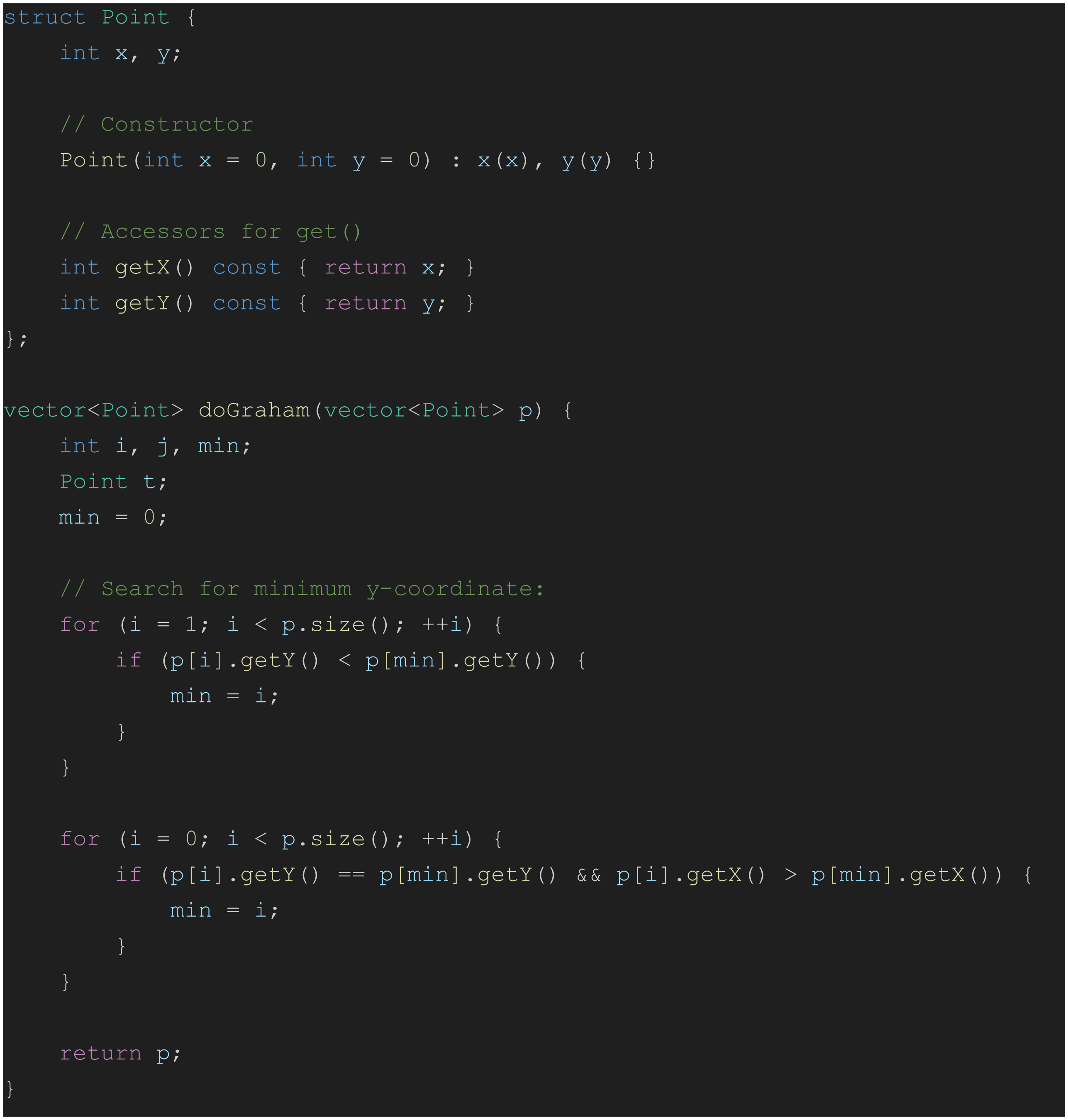
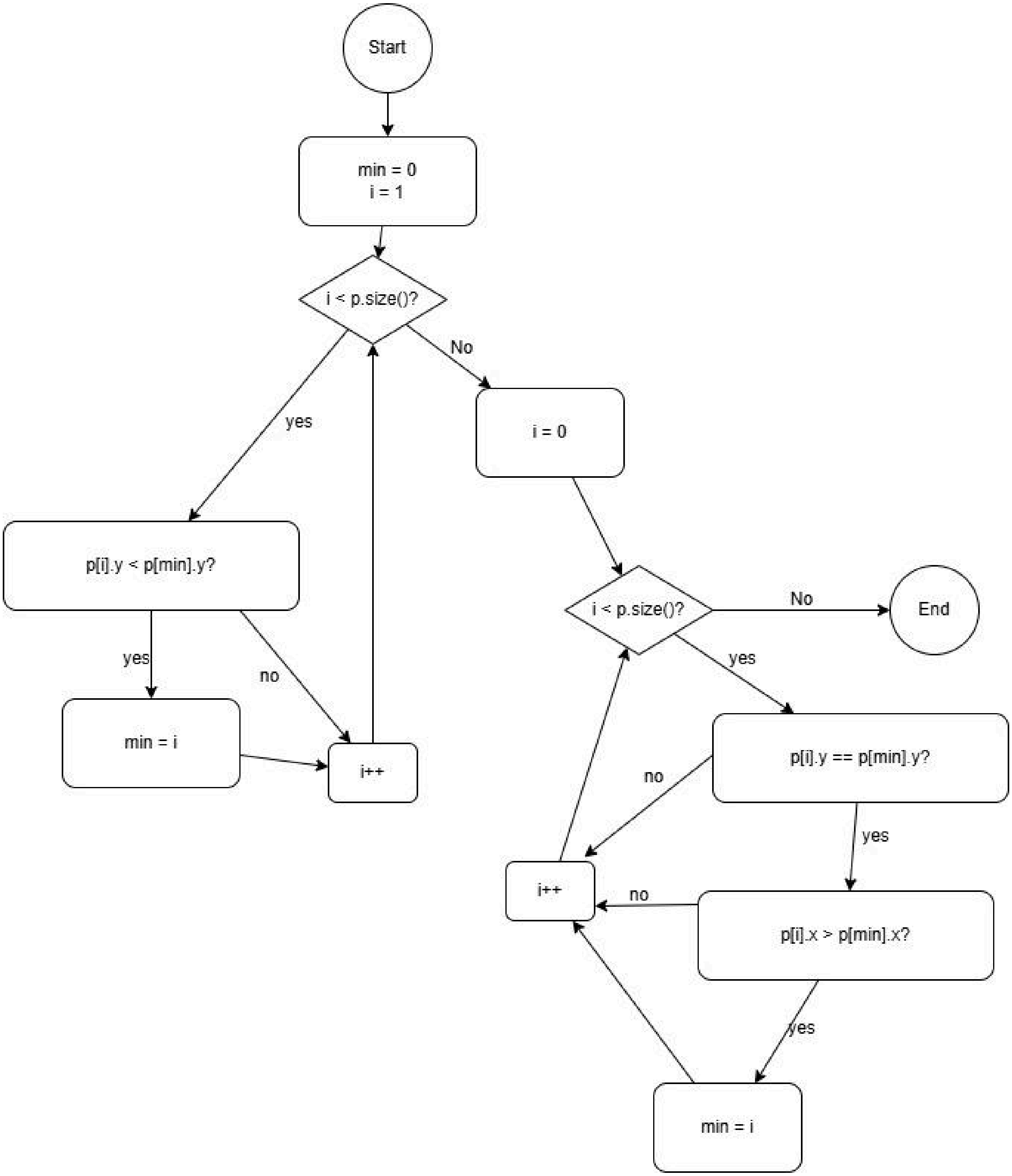
Q.1. The code below is part of a method in the ConvexHull class in the VMAP system. The following is a small fragment of a method in the ConvexHull class. For the purposes of this exercise, you do not need to know the intended function of the method. The parameter p is a Vector of Point objects, p.size() is the size of the vector p, (p.get(i)).x is the x component of the ith 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.

C++ code:



```
struct Point {
    int x, y;

    // Constructor
    Point(int x = 0, int y = 0) : x(x), y(y) {}

    // Accessors for get()
    int getX() const { return x; }
    int getY() const { return y; }
};

vector<Point> doGraham(vector<Point> p) {
    int i, j, min;
    Point t;
    min = 0;

    // Search for minimum y-coordinate:
    for (i = 1; i < p.size(); ++i) {
        if (p[i].getY() < p[min].getY()) {
            min = i;
        }
    }

    for (i = 0; i < p.size(); ++i) {
        if (p[i].getY() == p[min].getY() && p[i].getX() > p[min].getX()) {
            min = i;
        }
    }

    return p;
}
```

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



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

a. Statement Coverage

TC1: p = [(1, 7), (2, 3), (8, 1)]

- Covers cases where p.get(i).y < p.get(min).y is true.

TC2: p = [(1, 1), (2, 1), (3,1), (4,1)]

- covers cases where p.get(i).y == p.get(min).y and

p.get(i).x > p.get(min).x

b. Branch Coverage.

TC3: p = [(1, 2), (3, 3), (5, 9), (10, 15)]

- covers the false branch for condition

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

TC3: p = [(10, 15), (5, 9), (3, 3), (1, 2)]

- covers the true branch for condition

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

TC4: p = [(1, 1), (2, 1), (3, 1)]

- cover both true and false branches of

p.get(i).y == p.get(min).y and

p.get(i).x > p.get(min).x.

c. Basic Condition Coverage.

TC5: p = [(1, 2), (3, 3)]

- Covers p.get(i).y < p.get(min).y as false.

TC6: p = [(1, 5), (1, 3)]

- Covers p.get(i).y < p.get(min).y as true.

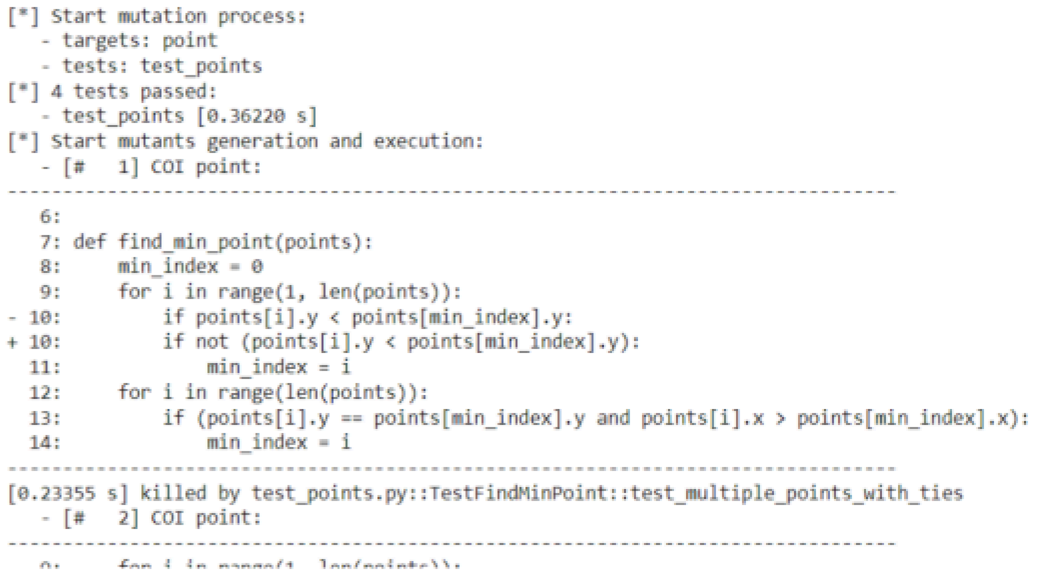
TC7: p = [(1, 1), (2, 1)]

- Covers p.get(i).y == p.get(min).y as true and p.get(i).x > p.get(min).x as true.

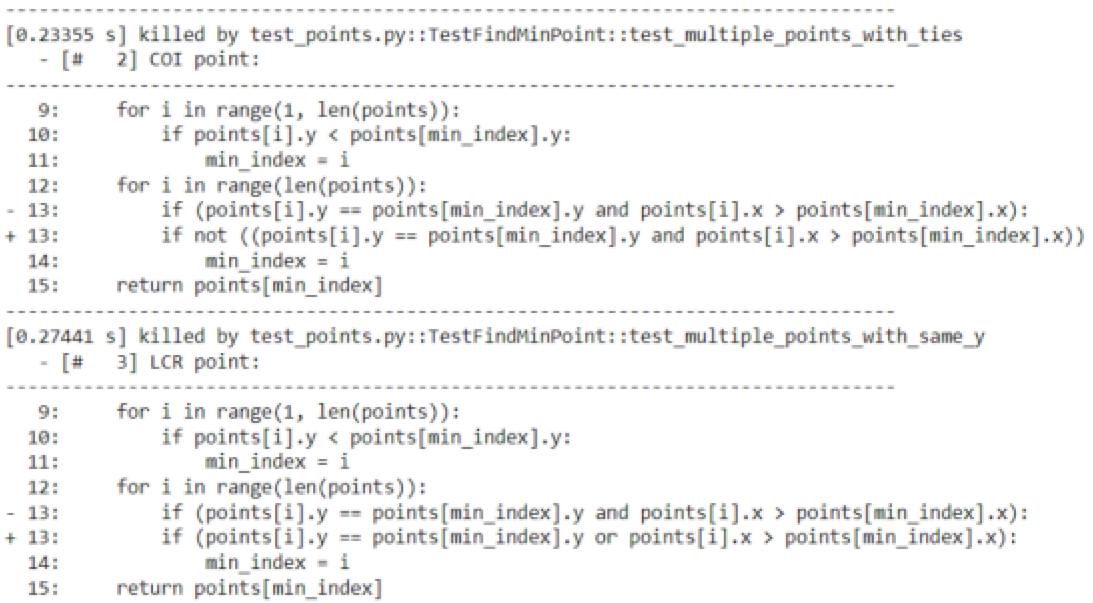
TC8: p = [(2, 2), (1, 1)]

- Covers p.get(i).y == p.get(min).y as false and p.get(i).x > p.get(min).x as false.

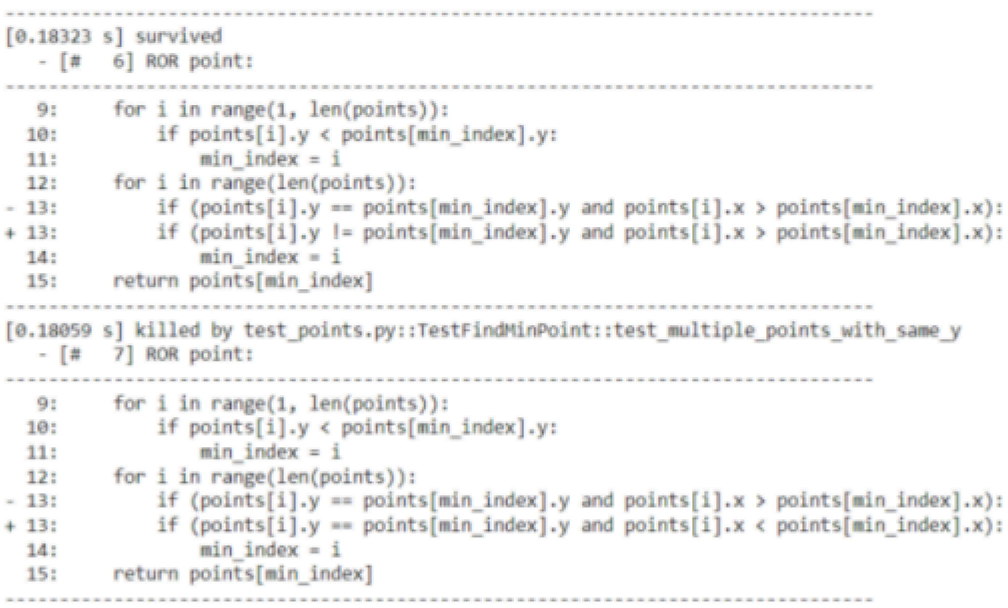
3. For the test set you have just checked can you find a mutation of the code (i.e. the deletion, change or insertion of some code) that will result in failure but is not detected by your test set. You have to use the mutation testing tool.



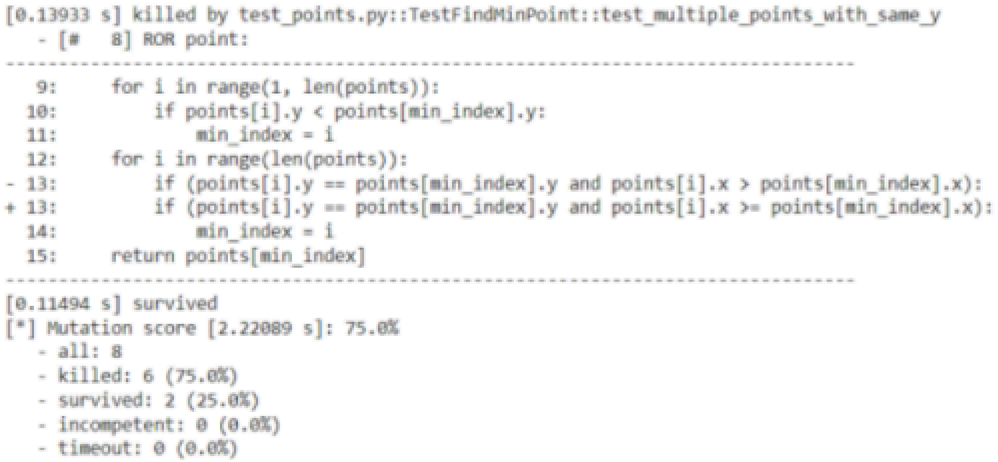
```
[*] Start mutation process:
   - targets: point
   - tests: test_points
[*] 4 tests passed:
   - test_points [0.36220 s]
[*] Start mutants generation and execution:
   - [#   1] COI point:
--------------------------------------------------------------------------------
    6:
    7: def find_min_point(points):
    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:
--------------------------------------------------------------------------------
    9:     for i in range(1, len(points)):
```



```
--------------------------------------------------------------------------------
[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%)
```

1. Deletion Mutation:

Remove min = i in the first if condition.

Mutation Code:

// Remove this line: min = i; if (((Point)

p.get(i)).y < ((Point) p.get(min)).y) {

// min = i; <- this line is removed

}

2. Insertion Mutation: Add min = 0 at the beginning of the second loop

Mutation Code:

for(i = 0; i < p.size(); ++i) { min = 0; //

Inserted line if (((Point) p.get(i)).y ==

((Point) p.get(min)).y &&

((Point) p.get(i)).x < ((Point) p.get(min)).x) {

min = i;

}

}

3. Modification Mutation:

Change p[i].y < p[min].y to p[i].y >

p[min].y in the first if condition.

Mutation Code:

if (((Point) p.get(i)).y > ((Point) p.get(min)).y) { // Modified

from < to > min = i;

}

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

```
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)


if __name__ == "__main__":

    unittest.main()
```