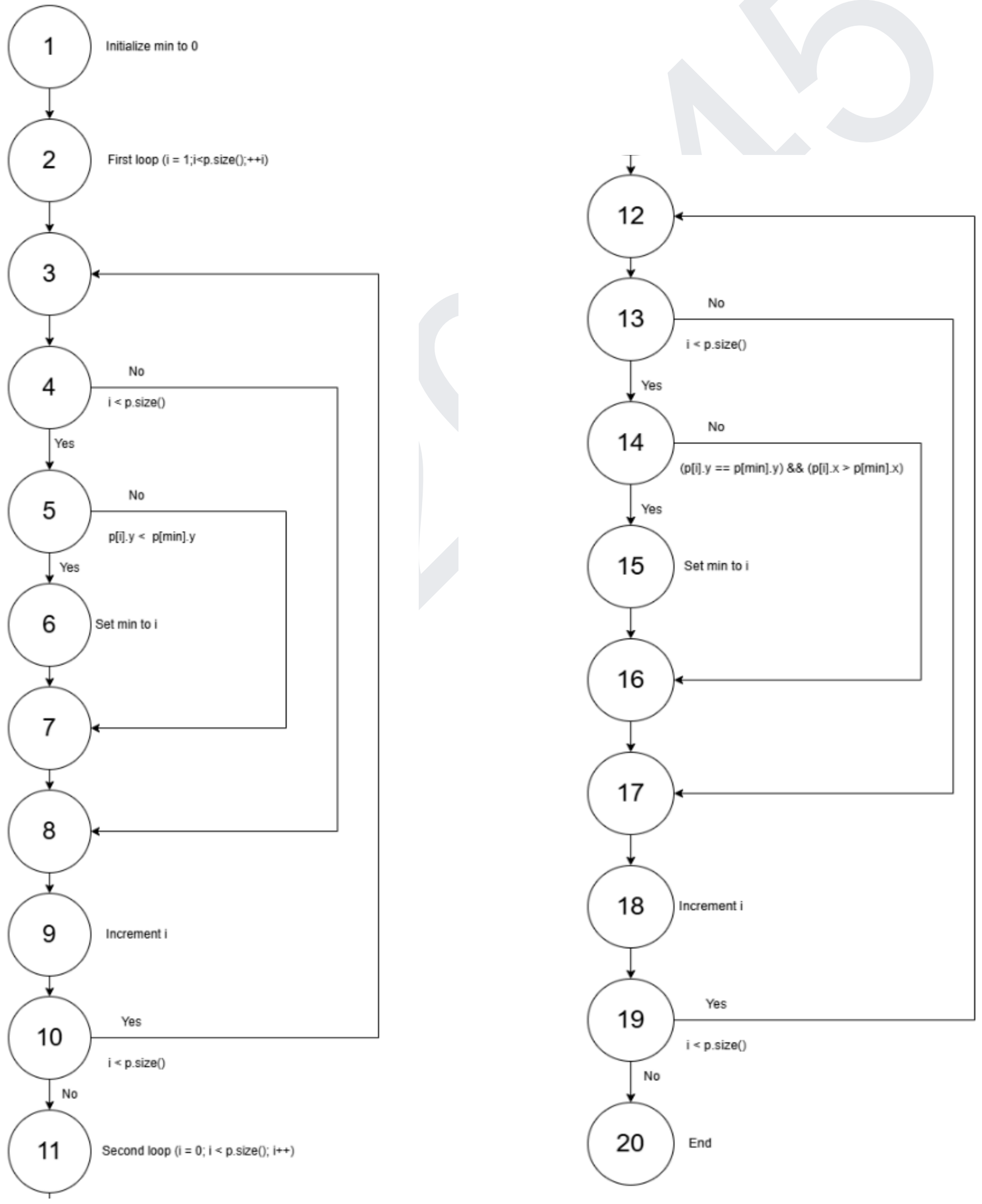
# Lab 9
# Mutation Testing

**Name - Desai Aditya Veeral Student ID - 202201451**

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

**Control Flow Graph:**



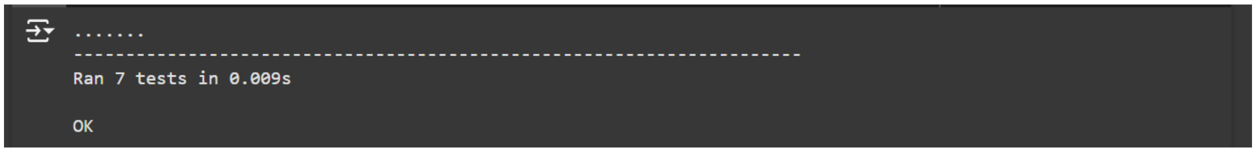
**2. Construct test sets for your flow graph that are adequate for the following criteria:**

> **a. Statement Coverage.**
> **b. Branch Coverage.**
> **c. Basic Condition Coverage.**

**Sol.**

```python
class Point:
    def __init__(self, x, y):
        self.x = x
        self.y = y

def do_graham(p):
    min_index = 0

    # search for minimum y-coordinate point
    for i in range(1, len(p)):
        if p[i].y < p[min_index].y:
            min_index = i

    # continue along the values with same y component
    for i in range(len(p)):
        if (p[i].y == p[min_index].y) and (p[i].x > p[min_index].x):
            min_index = i

    return min_index
    # assuming the function is meant to return the index of the min point


# Unit Tests
import unittest

class TestConvexHull(unittest.TestCase):
    def setUp(self):
        self.convex_hull = ConvexHull()

    def test_min_y_coordinate(self):
        points = [Point(1, 5), Point(2, 3), Point(4, 3)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, 2)  # Expected: 2
        self.assertEqual(result.y, 3)  # Expected: 3

    def test_same_y_max_x(self):
        points = [Point(1, 3), Point(2, 3), Point(4, 3)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, 1 #Expected:1(the first point with y=3)
        self.assertEqual(result.y, 3)  # Expected: 3

    def test_empty_points(self):
        with self.assertRaises(ValueError) as context:
            self.convex_hull.doGraham([] #Expect ValueError for empty list
        self.assertEqual(str(context.exception), "Point list is empty")

    def test_all_points_same(self):
        points = [Point(1, 1), Point(1, 1), Point(1, 1)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, 1)  # Expected: 1
        self.assertEqual(result.y, 1)  # Expected: 1

    def test_collinear_points(self):
        points = [Point(1, 1), Point(2, 2), Point(3, 3)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, 1)  # Expected: 1 (the first point)

    def test_negative_coordinates(self):
        points = [Point(-1, -1), Point(-2, -2), Point(-3, -3)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, -3)  # Expected: -3
        self.assertEqual(result.y, -3)  # Expected: -3

    def test_mixed_coordinates(self):
        points = [Point(1, 2), Point(-1, 2), Point(-1, -2), Point(1, -2)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, -1)  # Expected: -1 (minimum y, x = -1)

# Execute Unit Tests
if __name__ == '__main__':
    unittest.main(argv=['first-arg-is-ignored'], exit=False)
```

**Output:**



```
.......
----------------------------------------------------------------------
Ran 7 tests in 0.009s

OK
```

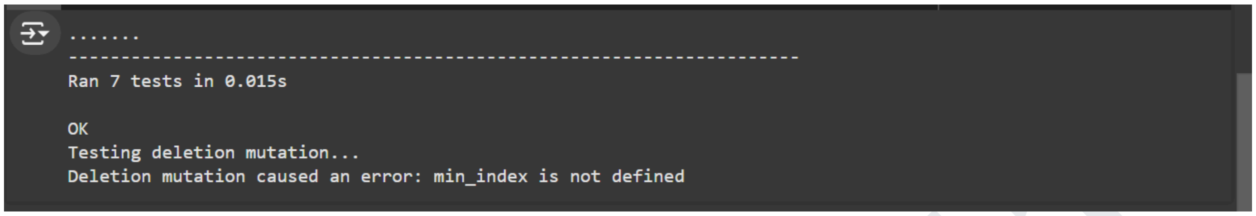
**3. For the test set you have just checked can you find a mutation of the code (i.e. the deletion, change or insertion of some code) that will result in failure but is not detected by your test set. You have to use the mutation testing tool.**
**Sol.**

**For Deletion:**
The line of min_index initialization was removed and the same error was caught as an exception in the output.

```python
# Mutation Testing Functions
def mutated_doGraham_deletion(p):
    # Mutation: Remove the initialization of min_index
    # min_index = 0  # This line is deleted
    for i in range(1, len(p)):
        if 'min_index' not in locals():
            raise ValueError("min_index is not defined")#Graceful handling
        if p[i].y < p[min_index].y:
            min_index = i
    # continue along the values with same y component
    for i in range(len(p)):
        if (p[i].y == p[min_index].y) and (p[i].x > p[min_index].x):
            min_index = i

    return min_index # This will cause an error

# Testing the mutations
points = [Point(1, 5), Point(2, 3), Point(4, 3)]\

# Testing deletion mutation
try:
    print("Testing deletion mutation...")
    result = mutated_doGraham_deletion(points)
    print(f"Deletion mutation result: ({points[result].x}, {
```

```
                                                            points[result].y})")
except Exception as e:
    print(f"Deletion mutation caused an error: {e}")
```

**Output:**



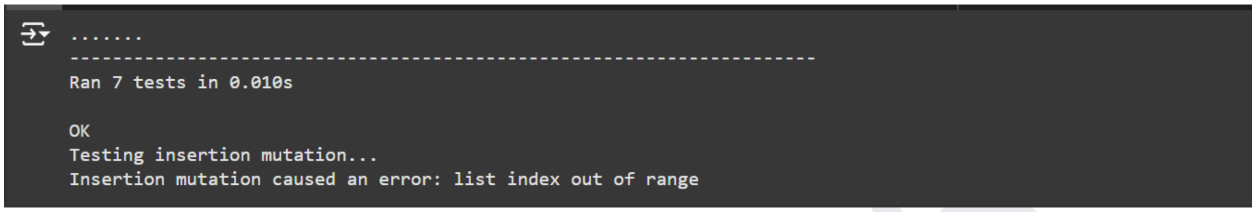
```
.......
----------------------------------------------------------------------
Ran 7 tests in 0.015s

OK
Testing deletion mutation...
Deletion mutation caused an error: min_index is not defined
```

## For Insertion:

The line of min_index initialization = 4 was added and the index out of bounds error was caught as an exception in the output.

```
# Mutation Testing Functions
def mutated_doGraham_insertion(p):
    # Mutation: Insert an invalid assignment
    min_index = 4 # Invalid initialization
    for i in range(1, len(p)):
        if 'min_index' not in locals():
            raise ValueError("min_index is not defined")  # Graceful
handling
        if p[i].y < p[min_index].y:
            min_index = i
    # continue along the values with same y component
    for i in range(len(p)):
        if (p[i].y == p[min_index].y) and (p[i].x > p[min_index].x):
            min_index = i

    return min_index # This will cause an error



# Testing the mutations
points = [Point(1, 5), Point(2, 3), Point(4, 3)]

# Testing insertion mutation
try:
    print("Testing insertion mutation...")
    result = mutated_doGraham_insertion(points)
    print(f"Insertion mutation result: ({points[result].x},
{points[result].y})")
except Exception as e:
    print(f"Insertion mutation caused an error: {e}")
```

**Output:**



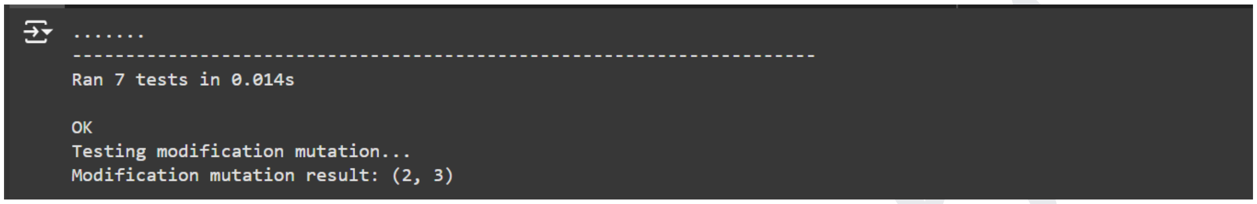
```
.......
----------------------------------------------------------------------
Ran 7 tests in 0.010s

OK
Testing insertion mutation...
Insertion mutation caused an error: list index out of range
```

## For Modification:

The comparison of `p[i].x > p[min_index].x` was modified to `p[i].x <= p[min_index].x` and hence the output came out wrong which could not be detected.

```
# Mutation Testing Functions
def mutated_doGraham_modification(p):
    # Mutation: Insert an invalid assignment
    # Mutation: Change > to <=
    min_index = 2
    for i in range(1, len(p)):
        if 'min_index' not in locals():
            raise ValueError("min_index is not defined")#Graceful handling
        if p[i].y < p[min_index].y:
            min_index = i
    # continue along the values with same y component
    for i in range(len(p)):
     # This will incorrectly give outputs for points as > got turned to <=
        if (p[i].y == p[min_index].y) and (p[i].x <= p[min_index].x):
            min_index = i

    return min_index # This will cause an error

# Testing the mutations
points = [Point(1, 5), Point(2, 3), Point(4, 3)]

# Testing modification mutation
try:
    print("Testing modification mutation...")
    result = mutated_doGraham_modification(points)
    print(f"Modification mutation result: ({points[result].x},
{points[result].y})")
except Exception as e:
    print(f"Modification mutation caused an error: {e}")
```

**Output:**



```
.......
----------------------------------------------------------------------
Ran 7 tests in 0.014s

OK
Testing modification mutation...
Modification mutation result: (2, 3)
```

**Error:** Got output (2,3) instead of (4,3)

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

**Sol.**

**These set of test cases cover every loop zero one or two times**

```
    def test_min_y_coordinate(self):
        points = [Point(1, 5), Point(2, 3), Point(4, 3)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, 2)  # Expected: 2
        self.assertEqual(result.y, 3)  # Expected: 3

    def test_same_y_max_x(self):
        points = [Point(1, 3), Point(2, 3), Point(4, 3)]
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        self.assertEqual(result.x, 1 #Expected:1(the first point with y=3)
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    def test_empty_points(self):
        with self.assertRaises(ValueError) as context:
            self.convex_hull.doGraham([] #Expect ValueError for empty list
        self.assertEqual(str(context.exception), "Point list is empty")

    def test_all_points_same(self):
        points = [Point(1, 1), Point(1, 1), Point(1, 1)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, 1)  # Expected: 1
        self.assertEqual(result.y, 1)  # Expected: 1

    def test_collinear_points(self):
        points = [Point(1, 1), Point(2, 2), Point(3, 3)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, 1)  # Expected: 1 (the first point)

    def test_negative_coordinates(self):
        points = [Point(-1, -1), Point(-2, -2), Point(-3, -3)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, -3)  # Expected: -3
        self.assertEqual(result.y, -3)  # Expected: -3

    def test_mixed_coordinates(self):
        points = [Point(1, 2), Point(-1, 2), Point(-1, -2), Point(1, -2)]
        result = self.convex_hull.doGraham(points)
        self.assertEqual(result.x, -1)  # Expected: -1 (minimum y, x = -1)
```