AAE1001 Introduction to Artificial Intelligence and Data Analytics in Aerospace and Aviation Engineering

Week 9 (Path Planning Programming Guide)

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Path Planning Example Code

A-star Example

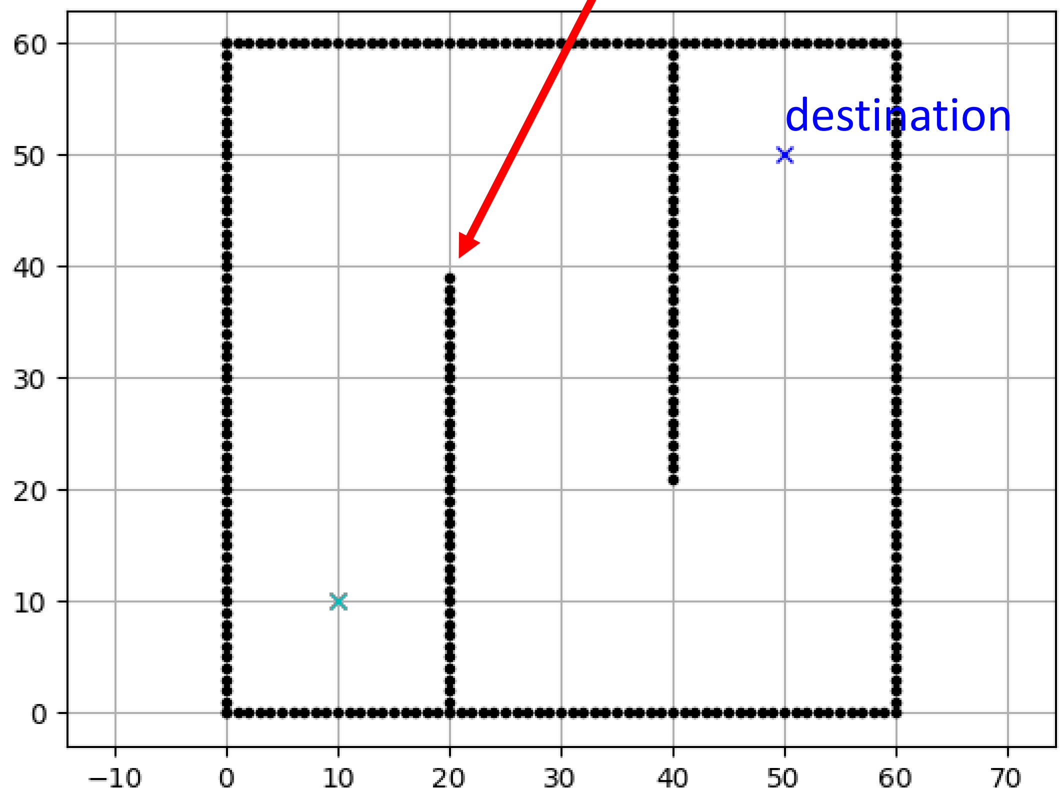
Each time A* enters a node, it calculates the cost: f(n) - n being the neighboring node

It travel to all of the neighboring nodes, and then enters the node with the lowest value of f(n)

These values we calculate using the following formula:

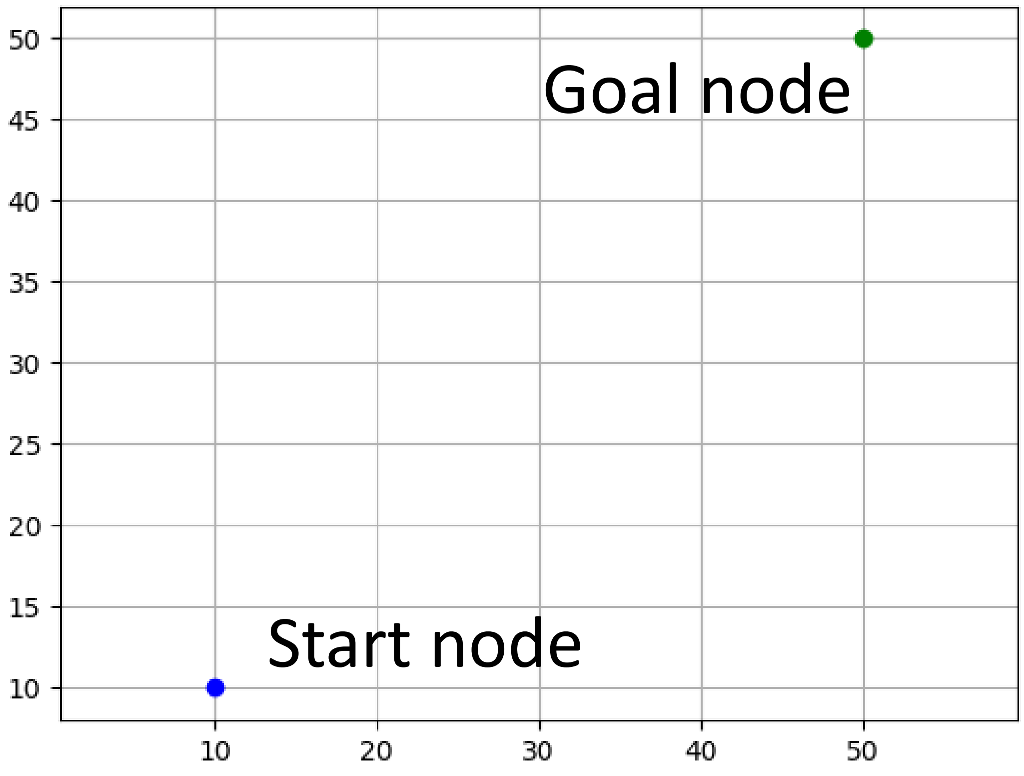
$$f(x,y) = g(x,y) + h(x,y)$$

Wall (obstacles) cannot go through!



https://towardsdatascience.com/a-star-a-search-algorithm-eb495fb156bb *Source: PythonRobotics*

Code Example (1): Set Up Start and Goal Node

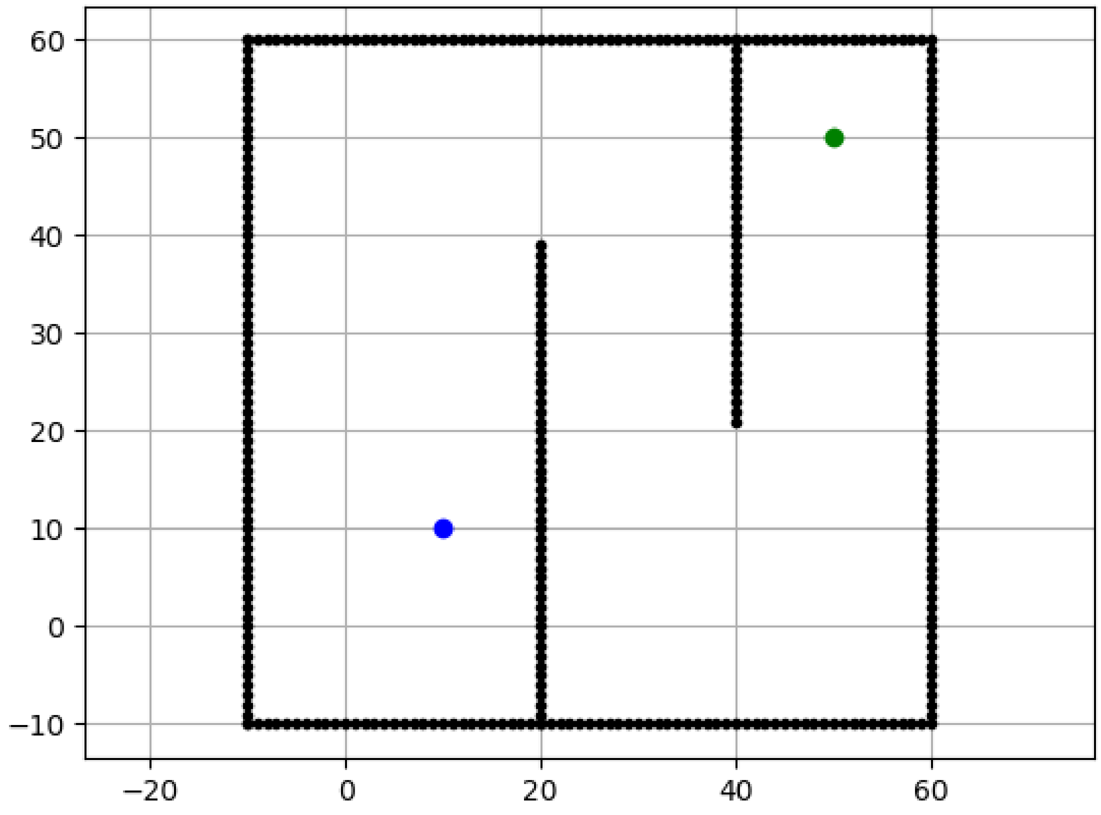


● Start node ● Goal node

```
# start and goal position
sx = 10.0  # [m]
sy = 10.0  # [m]
gx = 50.0  # [m]
gy = 50.0  # [m]
grid_size = 2  # [m]
```

Base code tutorial:
https://www.youtube.com/watch?v=PRKLhcG2kB0&ab_channel=POLYUIPNL

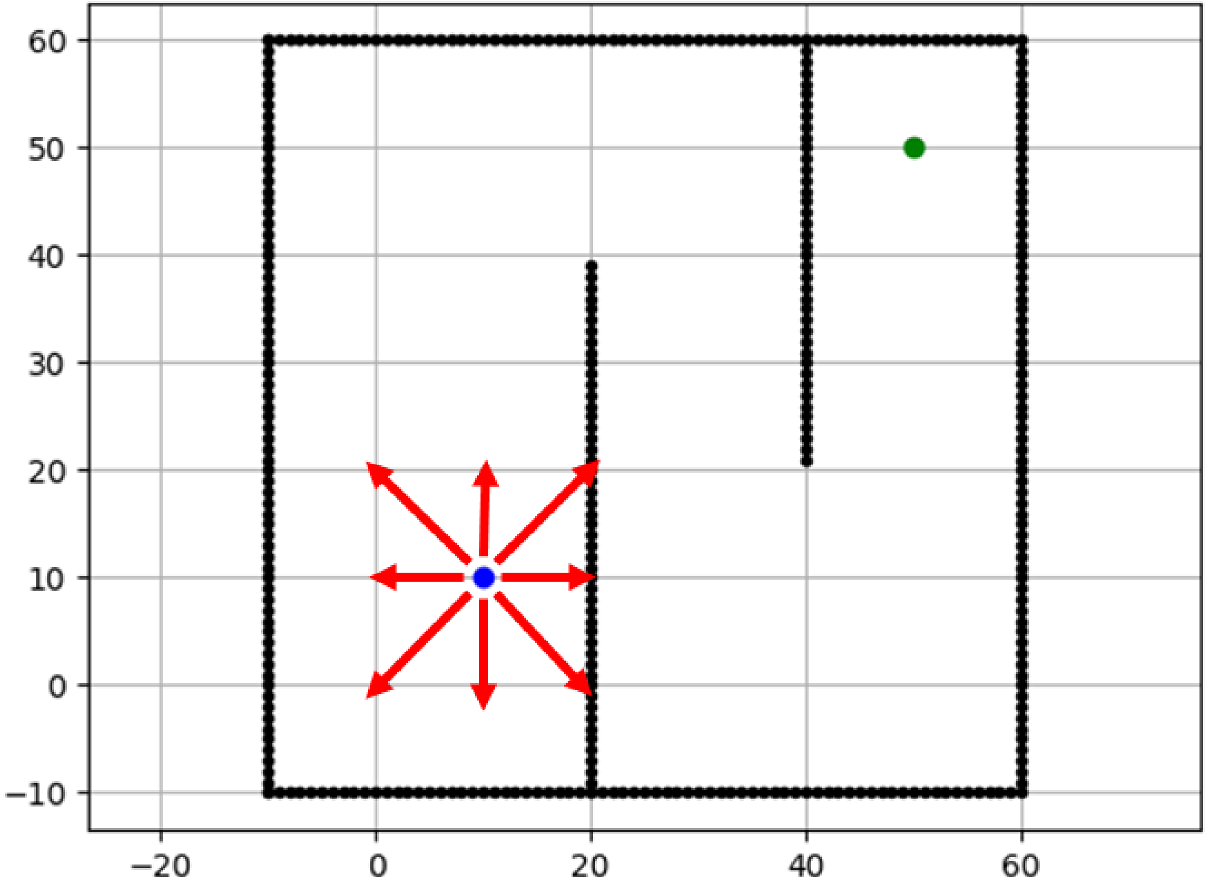
Code Example (2): Set Up Obstacle




```
# set obstacle positions
ox, oy = [], []
for i in range(-10, 60): # draw the button border
    ox.append(i)
    oy.append(-10.0)
for i in range(-10, 60):
    ox.append(60.0)
    oy.append(i)
for i in range(-10, 61):
    ox.append(i)
    oy.append(60.0)
for i in range(-10, 61):
    ox.append(-10.0)
    oy.append(i)
for i in range(-10, 40):
    ox.append(20.0)
    oy.append(i)
for i in range(0, 40):
    ox.append(40.0)
    oy.append(60.0 - i)
```

● Start node ● Goal node Obstacle (wall)

Code Example (3): Neighboring Node Search




```python
def get_neighbouring_node(): # the cost of the surrounding 8 points
    # dx, dy, cost
    motion = [[1, 0, 1],
              [0, 1, 1],
              [-1, 0, 1],
              [0, -1, 1],
              [-1, -1, math.sqrt(2)],
              [-1, 1, math.sqrt(2)],
              [1, -1, math.sqrt(2)],
              [1, 1, math.sqrt(2)]]

    return motion
```

Start node   Goal node   Obstacle (wall)

Code Example (4): Cost Calculation

Exact cost $g(x, y)$ calculation

```
node = self.Node(current.x + self.motion[i][0],
                 current.y + self.motion[i][1],
                 current.cost + self.motion[i][2], c_id)
```

Heuristic cost $h(x, y)$ calculation

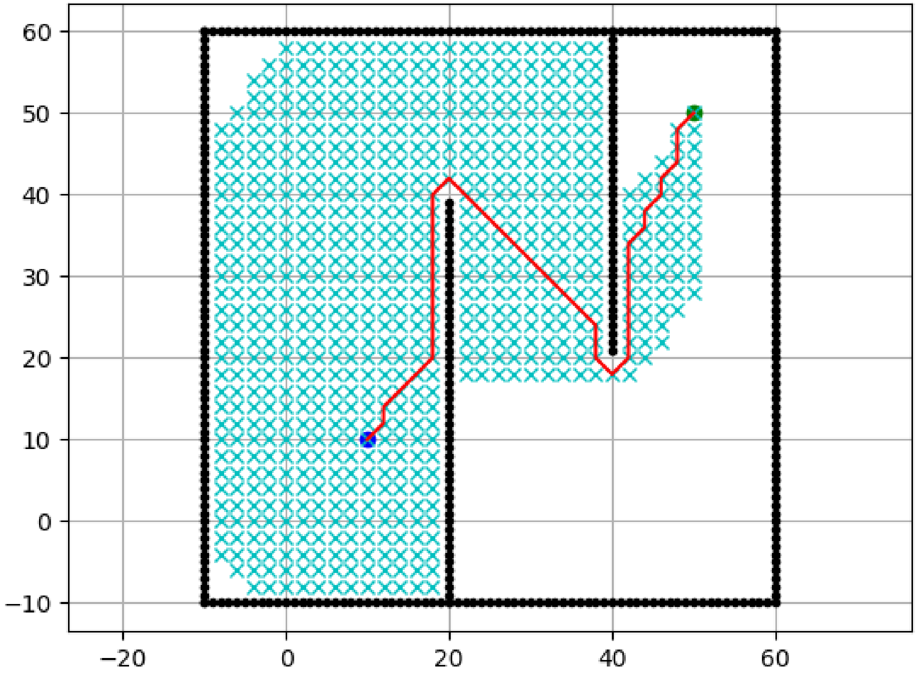
```
def calc_heuristic(n1, n2):
    w = 1.0  # weight of heuristic
    d = w * math.hypot(n1.x - n2.x, n1.y - n2.y)
    return d
```

Code Example (5): Calculation of Final Path

```python
def calc_final_path(self, goal_node, closed_set):
    # generate final course
    rx, ry = [self.calc_grid_position(goal_node.x, self.min_x)], [
        self.calc_grid_position(goal_node.y, self.min_y)] # save the goal node as the first point
    parent_index = goal_node.parent_index
    while parent_index != -1:
        n = closed_set[parent_index]
        rx.append(self.calc_grid_position(n.x, self.min_x))
        ry.append(self.calc_grid_position(n.y, self.min_y))
        parent_index = n.parent_index

    return rx, ry
```

Retrieve the optimal path from all passing through nodes (once being the current node)



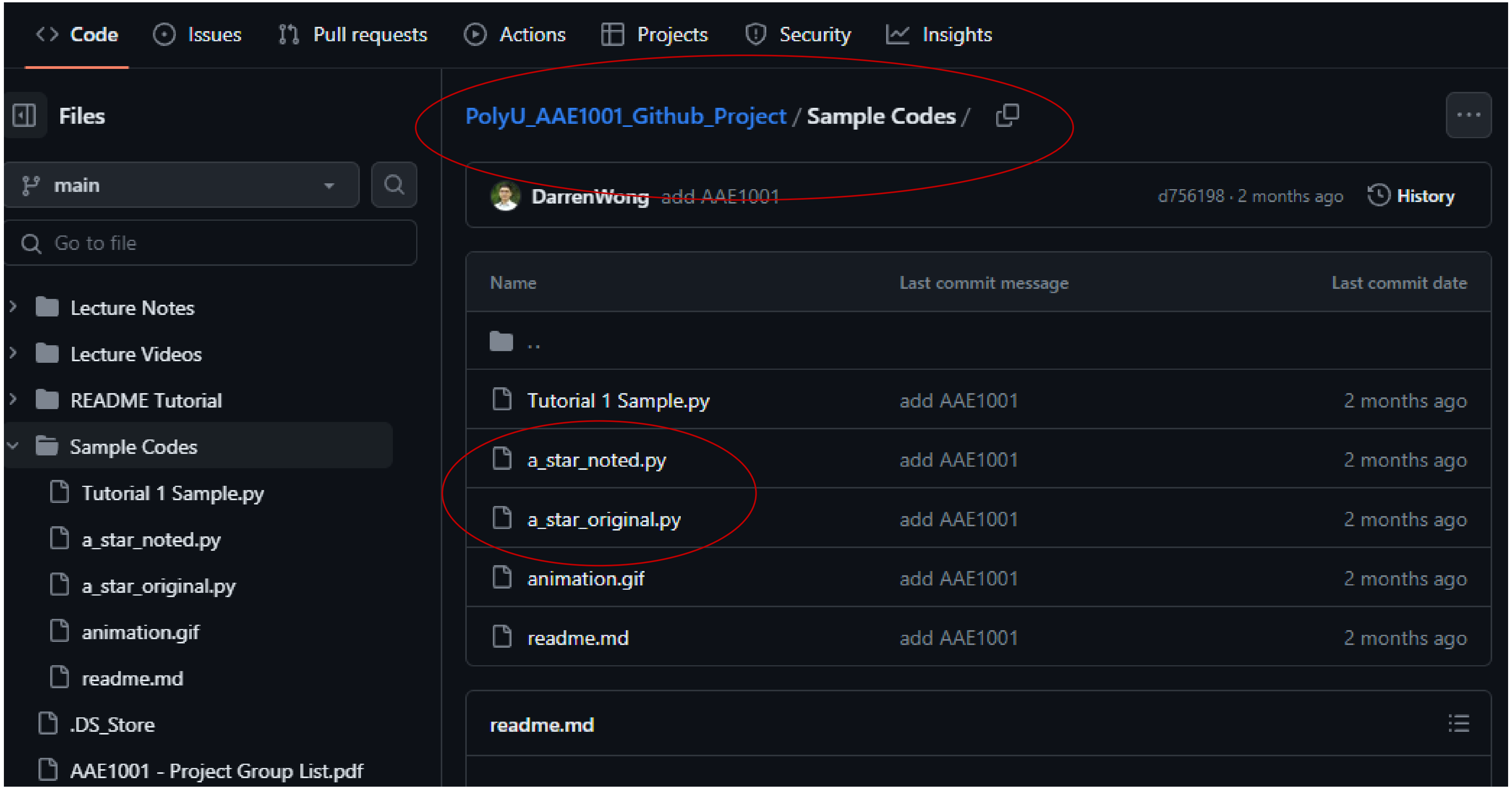
Path Planning Programming Guide

The Path Planning Code

- You can find the path planning code inside the course GitHub repository
- There are 2 set of codes:
  - A default one
  - A noted one
- The default one is a basic A* path planning code without any extra information and features
- The noted one provides an example of what your code should look like after modifications (Remember each group should complete a different set of obstacles and requirements)
- Repository link: https://github.com/IPNL-POLYU/PolyU_AAE1001_Github_Project

Base code tutorial: https://www.youtube.com/watch?v=PRKLhcG2kB0&ab_channel=POLYUIPNL

Where you can find the code



Noted Version Guide

- Line 50,51: Declaration of cost intensive area cost modifier
- Line 53: Declare cost per grid

```
34
35          self.resolution = resolution # get resolution of the grid
36          self.rr = rr # robot radis
37          self.min_x, self.min_y = 0, 0
38          self.max_x, self.max_y = 0, 0
39          self.obstacle_map = None
40          self.x_width, self.y_width = 0, 0
41          self.motion = self.get_motion_model() # motion model for grid search expansion
42          self.calc_obstacle_map(ox, oy)
43
44          self.fc_x = fc_x
45          self.fc_y = fc_y
46          self.tc_x = tc_x
47          self.tc_y = tc_y
48
49
50          self.Delta_C1 = 0.2 # cost intensive area 1 modifier
51          self.Delta_C2 = 0.4 # cost intensive area 2 modifier
52
53          self.costPerGrid = 1
54
```

Noted Version Guide

- Line 115: Showing the final calculation of total trip time
- Line 135-144: Adding additional cost during cost intensive area

```
103 if show_animation:  # pragma: no cover
104     plt.plot(self.calc_grid_position(current.x, self.min_x),
105              self.calc_grid_position(current.y, self.min_y), "xc")
106     # for stopping simulation with the esc key.
107     plt.gcf().canvas.mpl_connect('key_release_event',
108                                  lambda event: [exit(
109                                      0) if event.key == 'escape' else None])
110     if len(closed_set.keys()) % 10 == 0:
111         plt.pause(0.001)
112 
113 # reaching goal
114 if current.x == goal_node.x and current.y == goal_node.y:
115     print("Total Trip time required -> ",current.cost )
116     goal_node.parent_index = current.parent_index
117     goal_node.cost = current.cost
118     break
119 
120 # Remove the item from the open set
121 del open_set[c_id]
122 
123 # Add it to the closed set
124 closed_set[c_id] = current
125 
126 # print(len(closed_set))
127 
128 # expand_grid search grid based on motion model
129 for i, _ in enumerate(self.motion): # tranverse the motion matrix
130     node = self.Node(current.x + self.motion[i][0],
131                      current.y + self.motion[i][1],
132                      current.cost + self.motion[i][2] * self.costPerGrid, c_id)
133 
134     ## add more cost in cost intensive area 1
135     if self.calc_grid_position(node.x, self.min_x) in self.tc_x:
136         if self.calc_grid_position(node.y, self.min_y) in self.tc_y:
137             # print("cost intensive area!!")
138             node.cost = node.cost + self.Delta_C1 * self.motion[i][2]
139 
140     # add more cost in cost intensive area 2
141     if self.calc_grid_position(node.x, self.min_x) in self.fc_x:
142         if self.calc_grid_position(node.y, self.min_y) in self.fc_y:
143             # print("cost intensive area!!")
144             node.cost = node.cost + self.Delta_C2 * self.motion[i][2]
145         # print()
```

Noted Version Guide

- Line 263-270: Declaring motions for the aircraft
- Line 279-284: Declaring starting point and end point

```python
260     @staticmethod
261     def get_motion_model(): # the cost of the surrounding 8 points
262         # dx, dy, cost
263         motion = [[1, 0, 1],
264                   [0, 1, 1],
265                   [-1, 0, 1],
266                   [0, -1, 1],
267                   [-1, -1, math.sqrt(2)],
268                   [-1, 1, math.sqrt(2)],
269                   [1, -1, math.sqrt(2)],
270                   [1, 1, math.sqrt(2)]]
271 
272         return motion
273 
274 
275 def main():
276     print(__file__ + " start the A star algorithm demo !!") # print simple notes
277 
278     # start and goal position
279     sx = 0.0  # [m]
280     sy = 0.0  # [m]
281     gx = 50.0  # [m]
282     gy = 0.0  # [m]
283     grid_size = 1  # [m]
284     robot_radius = 1.0  # [m]
```

Noted Version Guide

- Line 309-329: Adding obstacles
- Line 337-348, Adding cost intensive areas (Hint: Refer to this part for your task 2!)

```
308     # set obstacle positions for group 9
309     ox, oy = [], []
310     for i in range(-10, 60): # draw the button border
311         ox.append(i)
312         oy.append(-10.0)
313     for i in range(-10, 60): # draw the right border
314         ox.append(60.0)
315         oy.append(i)
316     for i in range(-10, 60): # draw the top border
317         ox.append(i)
318         oy.append(60.0)
319     for i in range(-10, 60): # draw the left border
320         ox.append(-10.0)
321         oy.append(i)
322 
323     for i in range(-10, 30): # draw the free border
324         ox.append(20.0)
325         oy.append(i)
326 
327     for i in range(0, 20):
328         ox.append(i)
329         oy.append(-1 * i + 10)
330 
331     # for i in range(40, 45): # draw the button border
332     #     ox.append(i)
333     #     oy.append(30.0)
334 
335 
336     # set cost intesive area 1
337     fc_x, fc_y = [], []
338     for i in range(30, 40):
339         for j in range(0, 40):
340             fc_x.append(i)
341             fc_y.append(j)
342 
343     # set cost intesive area 1
344     tc_x, tc_y = [], []
345     for i in range(10, 20):
346         for j in range(20, 50):
347             tc_x.append(i)
348             tc_y.append(j)
```

Bonus !

- If you wish to do the trip cost (in terms of expense) calculation using the program, you should add the calculation function under line 117, inside the reaching goal condition

- It would be even better if the program could distinguish viable and non-viable aircraft types!

- Use the noted version as your example to modify your own code!

Bonus Showcase

When you add in a cost calculation function, the output should look something like this, it should be able to:

1. Calculate and show each aircraft types' operating costs
2. Mention which type might not be viable for certain scenarios

```
min_x: -10
min_y: -10
max_x: 60
max_y: 60
x_width: 70
y_width: 70
Total travelling time ->  93.35575746753788
A321 not viable!
Total cost of operating A330 in this scenario:  27360.167918740684
Total cost of operating A350 in this scenario:  30752.648960130347
```