Robotic Navigation and Exploration

HW1: Path Planning

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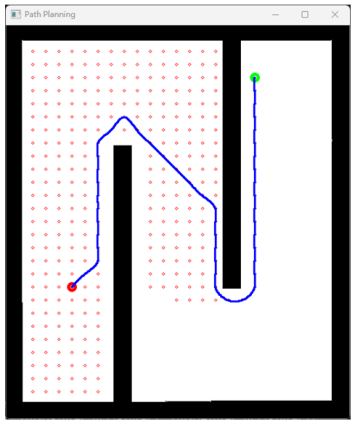
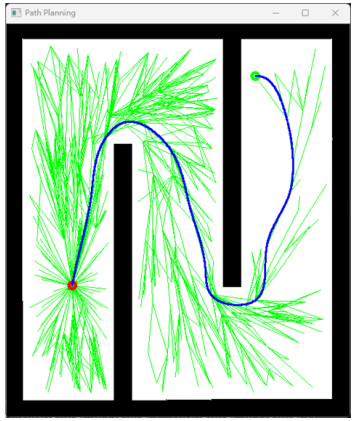
Score & Requirement

- **A*** (45%)
  - Implement path planning using A* algorithm
- **RRT*** (45%)
  - Implement path planning using RRT* algorithm
- **Report** (10%)
  - Briefly explain your implementation, writing a lot won't get you more points!

A*



RRT*



(No need to implement visualization)

A* Algorithm

- Cost Function: F(v) = g(v) + h(v)
- Consider both previous and future parameters:
  - g(v) : calculated path cost from start to v (Dijkstra)
  - h(v) : heuristic path estimation from v to target (BFS)

- Special condition of A*
  - h(v) = 0
    - degrade to Dijkstra's Algorithm
  - g(v)=0 or h(v) >> Edge weight
    - degrade to Best-First Search

[Practice] A* Algorithm

```
def planning(self, start=(100,200), goal=(375,520), inter=None, img=None):
        if inter is None:
            inter = self.inter
        start = (int(start[0]), int(start[1]))
        goal = (int(goal[0]), int(goal[1]))
        # Initialize
        self.initialize()
        self.queue.append(start)
        self.parent[start] = None
        self.g[start] = 0
        self.h[start] = utils.distance(start, goal)
        while(1):
            # TODO: A Star Algorithm
            break
```

./PathPlanning/planner_a_star.py

RRT Algorithm

```python
def planning(self, start, goal, extend_len=None, img=None):
        if extend_len is None:
            extend_len = self.extend_len
        self.ntree = {}
        self.ntree[start] = None
        self.cost = {}
        self.cost[start] = 0
        goal_node = None
        for it in range(20000):
            print("\r", it, len(self.ntree), end="")
            samp_node = self._random_node(goal, self.map.shape)
            near_node = self._nearest_node(samp_node)
            new_node, cost = self._steer(near_node, samp_node, extend_len)
            if new_node is not False:
                self.ntree[new_node] = near_node
                self.cost[new_node] = cost + self.cost[near_node]
            else:
                continue
            if utils.distance(near_node, goal) < extend_len:
                goal_node = near_node
                break
```

G.initialize(x_{start}) # Initialize Graph
for i=1 **to** max_iter **do**
  x_{rand} ← sample() # Sample the points in 2d space.
  $x_{nearest}$ ← nearest(x_{rand} , G) # Find the nearest point in graph.
  x_{new} ← steer(x_{rand} , $x_{nearest}$, step_size) # Collision detection.
  G.add_node(x_{new})
  G.add_edge(x_{new} , x_{parent})
  if $||x_{new} - x_{goal}|| <$ threshold **then**
    return G

./PathPlanning/planner_rrt.py

Steer

- Check if the line between two nodes is available.

```
def _steer(self, from_node, to_node, extend_len):
        vect = np.array(to_node) - np.array(from_node)
        v_len = np.hypot(vect[0], vect[1])
        v_theta = np.arctan2(vect[1], vect[0])
        if extend_len > v_len:
            extend_len = v_len
        new_node = (from_node[0]+extend_len*np.cos(v_theta), from_node[1]+extend_len*np.sin(v_theta))
        if new_node[1]<0 or new_node[1]>=self.map.shape[0] or new_node[0]<0 or new_node[0]>=self.map.shape[1] or
self._check_collision(from_node, new_node):
            return False, None
        else:
            return new_node, utils.distance(new_node, from_node)
```

./PathPlanning/planner_rrt.py

RRT* Algorithm

G. initialize(x_{start}) # Initialize Graph
for i=1 **to** max_iter **do**
  $x_{rand} \leftarrow$ sample() # Sample the points in 2d space.
  $x_{nearest} \leftarrow$ nearest(x_{rand} , G) # Find the nearest point in graph.
  $x_{new} \leftarrow$ steer(x_{rand} , $x_{nearest}$, step_size) # Collision detection.
  $X_{near} \leftarrow$ near_node(x_{new} , G)
  $x_{parent} \leftarrow$ best_parent(x_{parent} , X_{near}) # Re-Parent
  G.add_node(x_{new})
  G.add_edge(x_{new} , x_{parent})
  G.rewire(x_{new} , X_{near}) # Rewire
  if $||x_{new} - x_{goal}|| <$ threshold **then**
    return G

[Practice] RRT* Algorithm

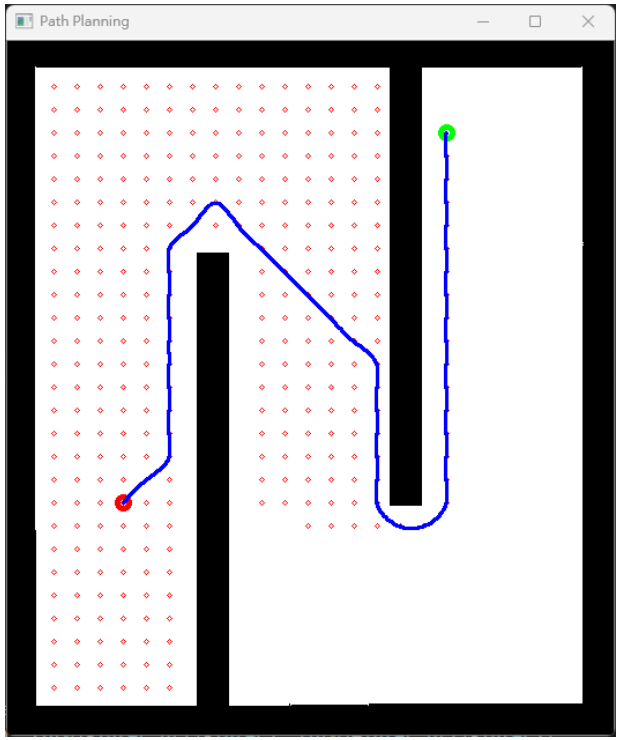
```
def planning(self, start, goal, extend_len=None, img=None):
        if extend_len is None:
            extend_len = self.extend_len
        self.ntree = {}
        self.ntree[start] = None
        self.cost = {}
        self.cost[start] = 0
        goal_node = None
        for it in range(20000):
            #print("\r", it, len(self.ntree), end="")
            samp_node = self._random_node(goal, self.map.shape)
            near_node = self._nearest_node(samp_node)
            new_node, cost = self._steer(near_node, samp_node, extend_len)
            if new_node is not False:
                self.ntree[new_node] = near_node
                self.cost[new_node] = cost + self.cost[near_node]
            else:
                continue
            if utils.distance(near_node, goal) < extend_len:
                goal_node = near_node
                break

            # TODO: Re-Parent & Re-Wire
```

./PathPlanning/planner_rrt_star.py

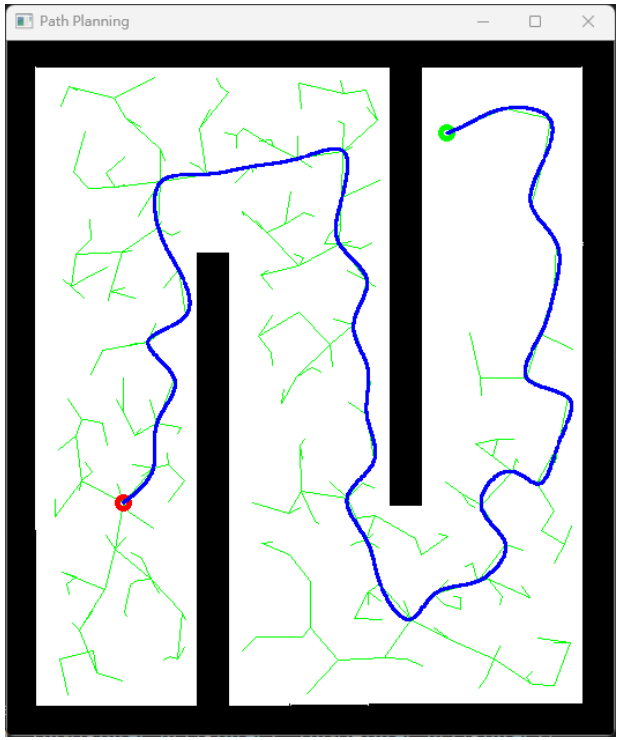
[Run] Path Planning

python path_planning.py -p [a_star/rrt/rrt_star] [--smooth]

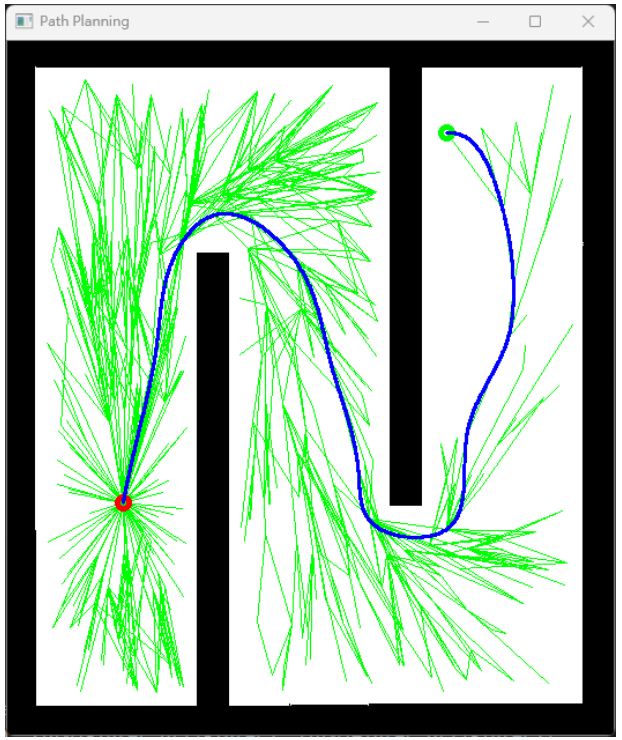
A*



RRT



RRT*



./03_path_planning.py

Remind

- Implementation should be done using following package:
  - Python standard library
  - opencv-python
  - numpy
- Check if you complete the "TODO" in the following files:
  - ./PathPlanning/planner_a_star.py
  - ./PlathPlanning/planner_rrt_star.py
- Use your student id to name your zip file (for example: 123456789_HW1.zip)
  - 10 points will be deducted for incorrect naming or filename extension

Q&A