RBE 550 -Motion Planning
HW2-Basic Search algorithms

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Code and algorithm explanation:

Q1. For PRM, what are the advantages and disadvantages of the four sampling methods in comparison to each other?

PRM:

Uniform Sampling:

Advantages:

1. Connectivity of samples is good

2. Implementation is easy.

Disadvantages:

1. For increase in size of map, there will be more nodes which is computationally expensive.

2. Explores all regions which is not required

Random Sampling:

Advantages:

- Easy Implementation

Disadvantages:

- Does not guarantee the path minimum number of samples.

Gaussian Sampling:

Advantages:

- Better connectivity for map contains obstacles with different shapes
- Few numbers of nodes to be explored

Disadvantages:

- Does not guarantee path in all scenarios.

Bridge Sampling:

Advantages:

- Finds path between narrow passages
- Less number of nodes, so computationally less expensive.

Disadvantages:

- Does not guarantee path in all scenarios.

Q2) For RRT, what is the main difference between RRT and RRT*? What change does it make in terms of the efficiency of the algorithms and optimality of the search result?

The first difference between RRT and RRT* is that, in RRT the new sampled point connects with the nearest node available from the tree irrespective of the cost, where in case of the RRT*, the neighbour nodes are searched to find the best path cost and the new node then connects to that neighbour node.

And the second difference is the rewiring of the neighbouring nodes in RRT* with respect to the new node, where as it RRT it won't do it.

Efficiency:

In terms of efficiency RRT computationally less expensive sub optimal path than RRT*. In RRT* rewiring the path with less cost will be performing for a defined number of iterations makes it longer time to achieve optimal path.

Optimality.

RRT* converged to an optimal path with time whereas RRT quickly gives suboptimal path.

Q3) Comparing between PRM and RRT, what are the advantages and disadvantages?

PRM:

Advantages:

- Probabilistically complete
- More Sample points better connectivity and better path

Disadvantages:

- It cannot be use for dynamic obstacle avoidance as it becomes computationally expensive for replanning.
- Better connectivity depends on type of sampling method. So based on problem we need to choose appropriate sampling method.

RRT:

Advantages:

- Computationally less expensive
- Convergence is faster.
- Probabilistic Completeness
- It finds the path in complex scenarios if it exists, provided enough samples are generated.
- It can be used to find path even with dynamic obstacles.

Disadvantages:

- Does not guarantee optimal Path
- More samples need to generate to improve path

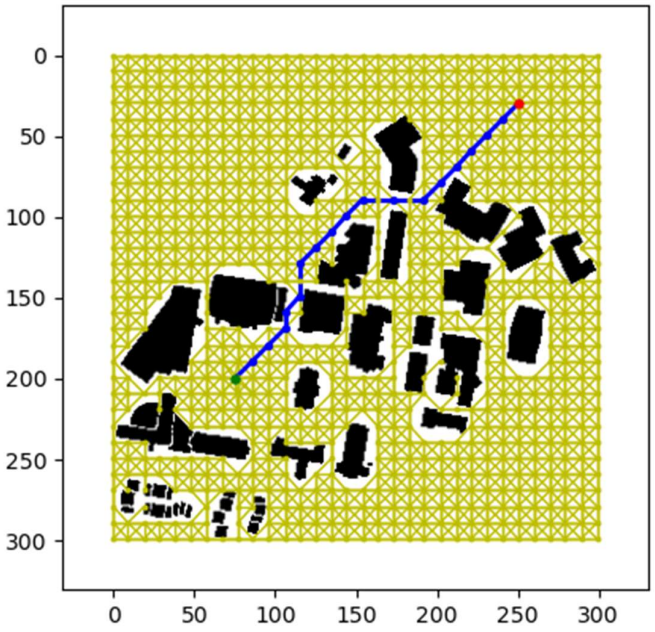
Algorithm results and explanation:

PRM:

Uniform Sampling:

Sampled points are generated using boundary limits with defined constant distance between each point. Each sample was checked for collision. If sample lies in free space, then samples are added to graph nodes. Shortest Path in the graph given by Dijkstra's algorithm.

Result:

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01_Assignments/03_Standard_Search_Algorithms')
The constructed graph has 838 nodes and 3996 edges
The path length is 263.92
```

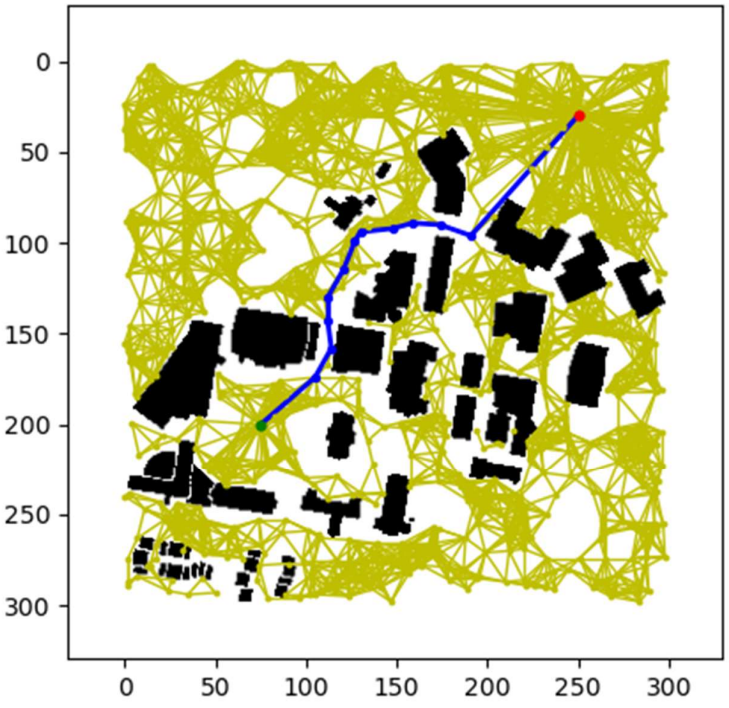
Random Sampling:

Each sample point is chosen randomly within the boundary limits.

If the sample does not lie on obstacle, then add point as node in the graph. For all samples points build a graph. Using Dijkstra algorithm shortest path can be found on the generated graph.

More sample points better connectivity in the graph.

Result:



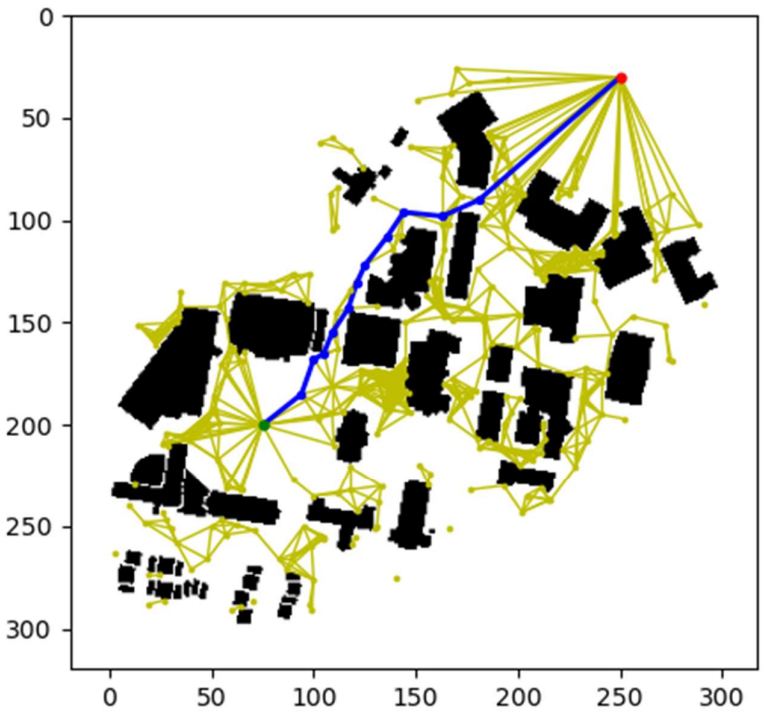

```
The constructed graph has 830 nodes and 4546 edges
The path length is 282.06
```

Gaussian Sampling:

First a point chosen randomly, and another point is chosen by Gaussian distribution with mean as sampled point. If sampled point is in obstacle and Gaussian sample point is in free space, then the point in free space must be close to obstacle. Using this approach, we can sample a defined number of points.

This will ensure connectivity around obstacles. The graph shown below contains nodes mostly distributed near obstacles.

Result:

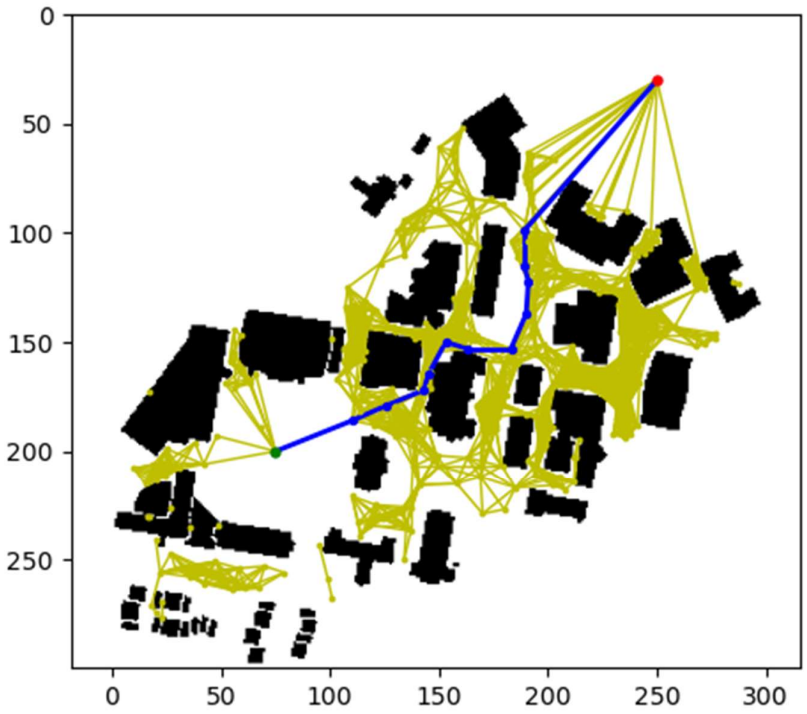



```
The constructed graph has 332 nodes and 963 edges
The path length is 279.36
```

Bridge Sampling:

This is very similar to gaussian sampling. The key difference is that both the points are taken on obstacle and 3rd point is found which is in free space and between these two points.
This ensures the node between narrow passages. As number of sampled points decreases drastically 20,000 points were taken to sample the space.
As shown in figure below, the sampled points are between the two obstacles.

This ensures better connectivity of two clusters of the networks.




```
The constructed graph has 352 nodes and 2131 edges
The path length is 262.01
```

RRT:

It is a sampling-based algorithm which expands its nodes in the form Tree and explores free spaces.

For each sample point check for nearest node and implement RRT extend method.

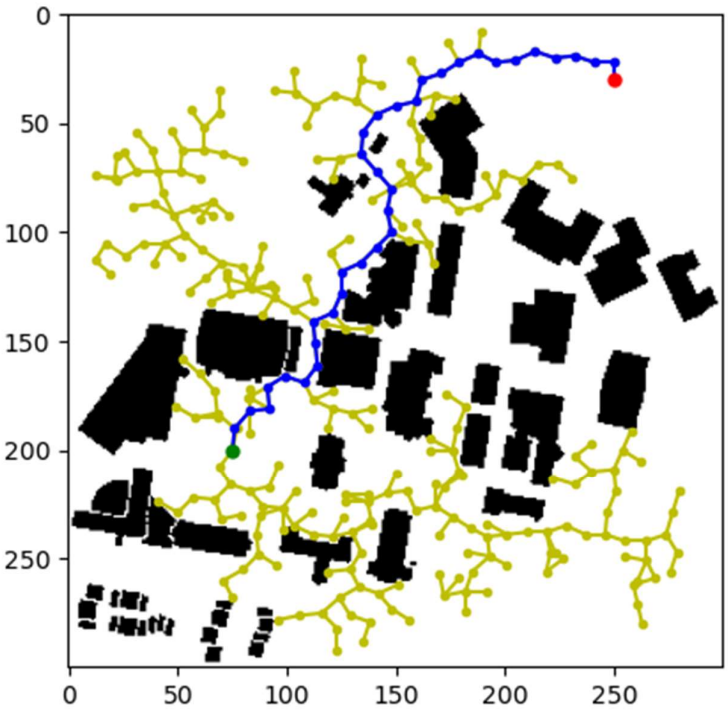
We implemented RRT extend function which add node with fixed distance along the sampled point.

Collision check is implemented using Bresenham's line algorithm.

Before extending node in the tree, collision is checked.

Once tree reaches goal nearby, we will extend the goal as new.

Backtracking from goal node parent to start provides the path.

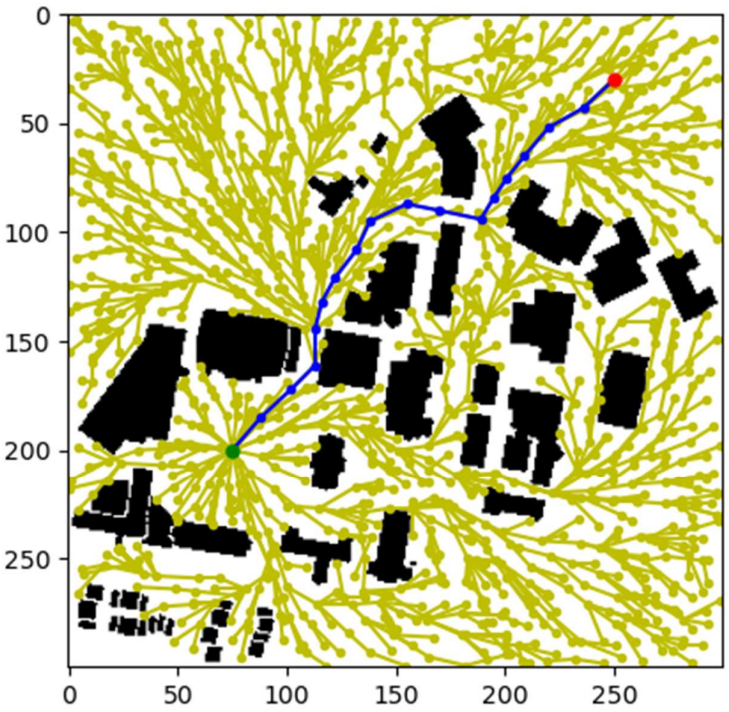



```
It took 277 nodes to find the current path
The path length is 341.01
```

RRT*:

Implementation is same as RRT except the rewire function and path cost. Instead of connecting the new node to the nearest node, the neighbours of the new node are considered and the cost-to-come from start for the new node is checked through all the neighbours. The neighbour that provides the least cost-to-come to the new node is chosen as the parent for the new node. Better path can be found with the increase in number of iterations. This is because nodes will be rewired if better path cost is found

Results:




```
It took 1250 nodes to find the current path
The path length is 271.50
```

References:

Implemented code by understanding concepts from below link

1. https://toulik.medium.com/probabilistic-roadmap-e99c69bf96df