RBE 550 - PRM Algorithm Implementation

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

Four sampling methods, namely Uniform Sampling, Random Sampling, Gaussian Sampling and Bridge Sampling have been implemented. The main advantages and disadvantages are as follows:

Uniform Sampling

Advantages: The Uniform Probabilistic Roadmap method is said to be probabilistically complete, which implies that if there is a possible path, the algorithm will most likely find it. Additionally, uniform sampling is simple and easy to implement.

Disadvantages: Has higher computational requirements as the workspace increases in size. It additionally requires further parameter tuning such as optimizing the step size when gathering the sampling points etc.

Random Sampling

Advantages: Its simple and easy to implement. Prone to less bias due to randomness of sampling.

Disadvantages: As the sampling is random, the sampled points may not cover the grid space evenly leading to uneven distribution in the sampling space. This means sometimes you might need a greater number of points to find the feasible path. As the workspace increases in size, the memory requirements and computation requirements in higher configurations also increases.

Gaussian Sampling

Advantages: Gaussian sampling is efficient in terms of computation as it minimizes the number of samples required to represent the configuration space. Faster compared to Uniform Sampling as the number of points sampled in configuration space is lower.

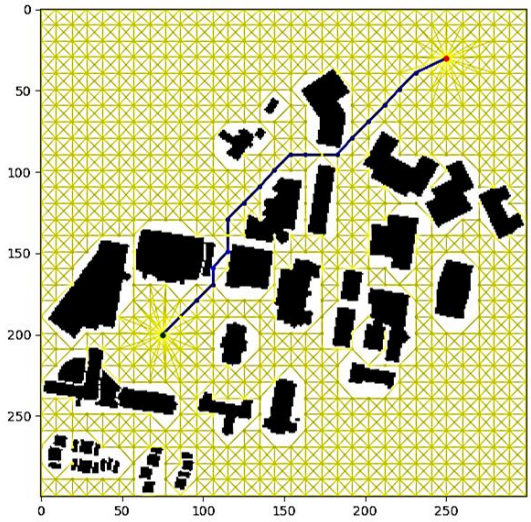
Disadvantages: If the space has complex shapes or obstacles that are not regular, the Gaussian method may not be able to create an accurate representation of the space. In such situations, other methods of sampling may be more appropriate than Gaussian.

Bridge Sampling

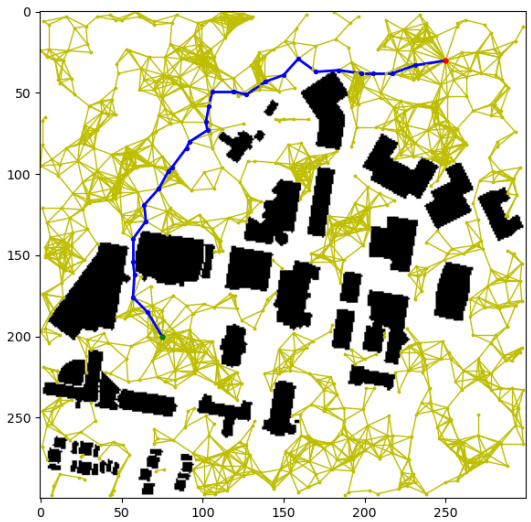
Advantages: The approach is fairly reliable and can offer a collision-free path even in extremely cluttered and complex environments. Is good at finding paths in between narrow passages and constricted environments.

Disadvantages: Path obtained may not be optimal as points are sampled through random distribution.

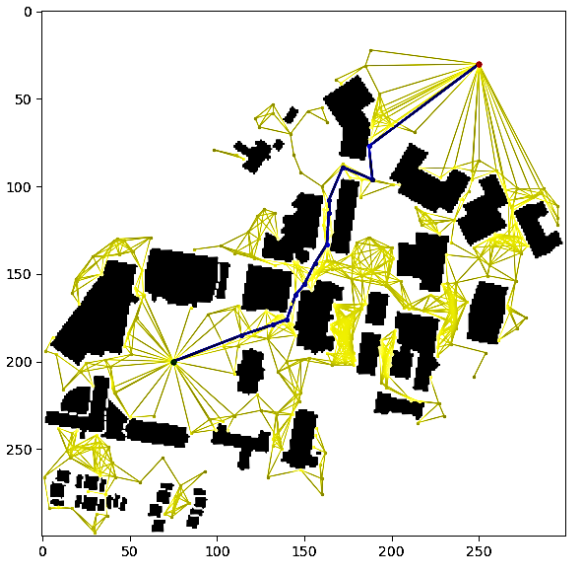
The results for the different sampling methods:



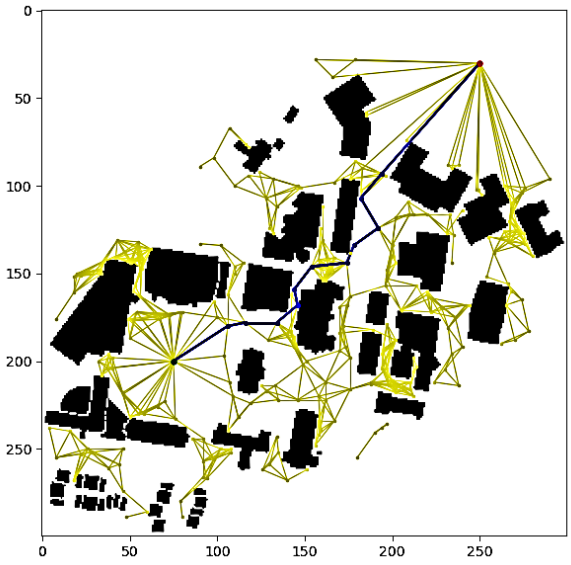
Uniform Sampling



Random Sampling



Gaussian Sampling



Bridge Sampling

As we can see from the results, Uniform sampling covers the entirety of the 2D grid while sampling the points at a constant step size. The shortest path is taken diagonally to each smaller grid elements. Uniform Sampling always finds a path if one exists, i.e. its probabilistically complete. In the case of random sampling, the nodes are unevenly distributed leading to a need for finer parameter tuning when searching for neighboring nodes as the uneven density in empty spaces can lead to disjointed trees. Gaussian Sampling collects nodes closer to the obstacle space as we can see in the concentration of sampled nodes around the black 2D obstacles. This helps find feasible paths in highly cluttered environments. Bridge sampling samples points between two obstacles. Due to this the nodes are found more frequently in narrow or gaps between obstacles which helps navigation in narrow spaces but leads to disjointed trees around the corners of obstacles.

Algorithm Implementation:

The algorithm has 4 separate methods for sampling of points for each of the PRM techniques. We have separate functions for determining the presence of obstacle between two paths and also for measuring the Euclidean distance (weights) between two sampled points. We then find a set number of closest neighboring nodes for each of the sampled points in all the cases using KD Tree. A feasible path is determined for this subset of neighboring nodes to create the mesh or network of paths. We then query to find the feasible path from start to goal. But as the start and goal can lie outside the network, we sample points in their neighborhood from the sampling space and connect the start and goal to the grid through them. This way we are able to solve for a feasible path in all of the 4 cases. The only difference in their implementation is the way the points are sampled in each of the 4 cases.