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PRM Algorithm Implementation

Probabilistic Roadmap Algorithm:

PRM Algorithm is used in motion planning to generate a roadmap for robots in a given map or environment. This technique uses various sampling methods to generate a roadmap of the given environment. This roadmap is usually an undirected graph or grid, In this case, I have used various sampling methods such as uniform, random, gaussian, and bridge sampling to generate various roadmaps and analyzed the performance of each sampling method by observing the path and distance.

Once the roadmap is created, *qstart* is selected and attempted to connect with sampled points starting with the closest node. Similarly, *qgoal* is selected and allowed to connect with the sampled points. Once the start and goal points are connected successfully then the path is searched, in this assignment, Dijkstra's algorithm is implemented to find the path given the start and goal node.

Sampling Methods

1. **Uniform Sampling**: This method of sampling involves random sampling through the robot's workspace or environment. This method ensures that the discretized workspace is uniformly sampled throughout. Once the configurations are generated, they are checked for collisions and then appended as sampled points.

   Advantages:

   - It is easy to implement and has a less computational load.
   - It covers the entire robot environment which allows the algorithm to evaluate all areas in the environment.

   Disadvantages:

   - The sampling is not efficient in the high-resolution environment as it is computationally expensive.
   - Not effective in narrow gaps and bridges environments in such cases other sampling methods are more efficient.

2. **Random Sampling:** In this sampling method, a set of random configurations is generated by selecting a set of random points in the environment. Once the configurations are generated, they are checked for collisions and then appended as sampled points.

   Advantages:

   - As uniform sampling is the most naïve method to implement sampling thus making it easy to implement.
   - It can generate more samples quickly as it starts sampling making it efficient in smaller environments.

   Disadvantages:

   - Due to randomness, there is a higher chance that the generated samples may have invalid configurations.
   - Similarly, like a uniform sampling when the resolution of the environment increases it becomes computationally expensive.

3. **Gaussian Sampling:** In Gaussian sampling, a point is selected as the mean in the gaussian or the normal distribution. Another point is selected from the gaussian distribution centered at the first point. If both the picked points are collision or collision-free, they are discarded.

   Advantages:

   - Gaussian sampling allows us to manage the parameter such as the variance or the standard deviation allowing us to manage the sampling points in the environment.
   - It works efficiently on larger maps by reducing sampling time.

   Disadvantages:

   - The parameters are sensitive making it difficult to tune them, a slight change in the variance can cause different samples to generate.
   - The probability of the gaussian sample distribution working in narrow passages is less.

4. **Bridge Sampling:** In bridge sampling first, we take a point that is in a collision and then sample another point in the neighbor using the Gaussian distribution. If the point found by the gaussian distribution is in a collision, then find the mid-point of the two points and later check if the mid-point falls in a collision if yes then append it.

   Advantages:

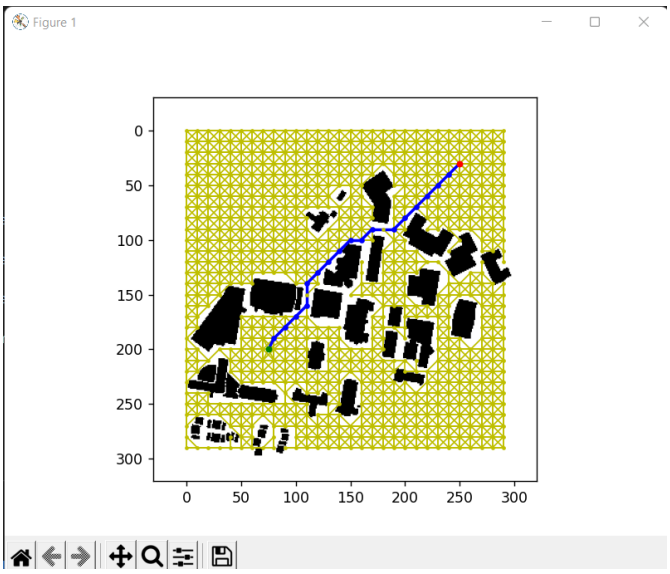
   - It leverages the advantages of gaussian sampling along with its capabilities to sample in bridges and narrow passages making it ideal for environments consisting of narrow passages.

   Disadvantages:

   - This sampling is not effective in areas having a lot of open areas in the environment.
   - Since this uses the gaussian distribution the tuning parameters are sensitive such as the standard deviation and variance.

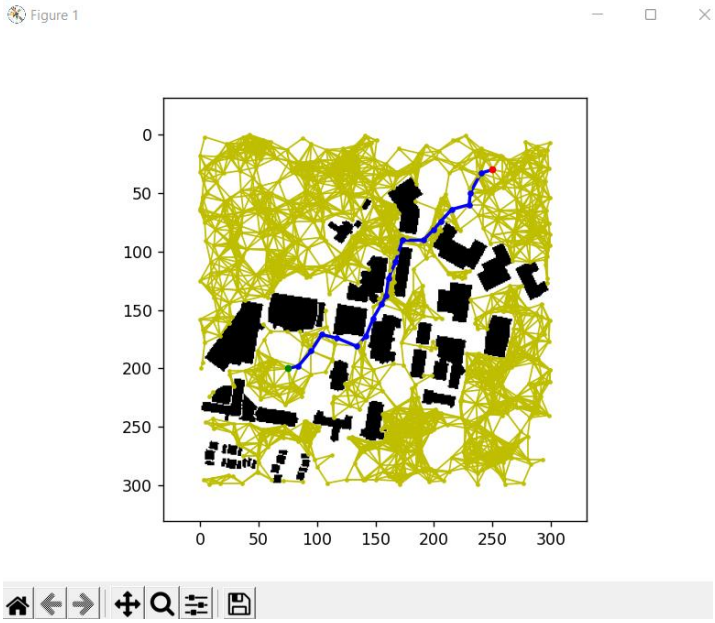
RESULTS

1. **Uniform Sampling:**



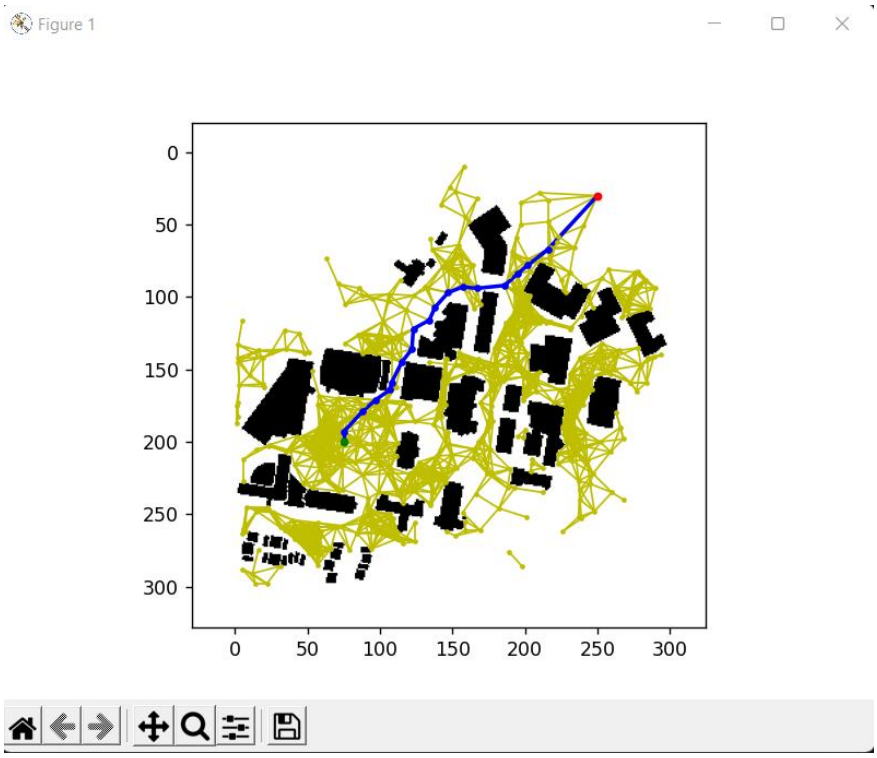
From the above result of the given uniform sampling method. We can see the samples are uniformly distributed over the grid and the path is found.

2. Random Sampling:



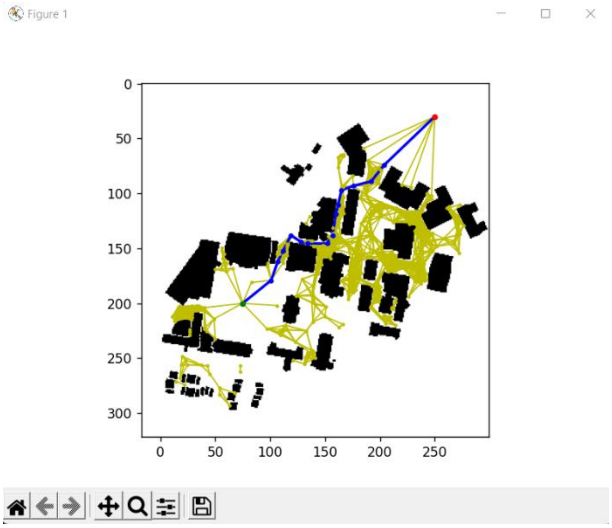
The above results show random points sampled into the workspace and the path generated above generated above is based on these points.

3. Gaussian Sampling:



The above output shows the gaussian sampling, as it is evident from the image that the points are centered, and sampling is done around them.

4. Bridge sampling:



The above image shows the output from bridge sampling, it is evident that the samples have been done on various narrow passages and gaps as well.

References:

1. Kevin M. Lynch and Frank C. Park: MODERN ROBOTICS MECHANICS, PLANNING, AND CONTROL.
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6. Lecture Slides