Probalistic RoadMap Generation on L-Shape Robot with Point Representation

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***Abstract*—This project intends to implement the Probabilistic Roadmap algorithm on a L-shape robot with generalization of robot physical features and modified local planner.**

I. Introduction

As a very common algorithm in sampling-based motion planning, Probabilistic RoadMap (PRM) is often used on robot path planning. This project is intended to utilize this algorithm to solve robot motion planning problem with special shape, and this project assumes the joint part of this robot is static, which means there is not transformation or twisting of these two arms around the joint point.

II. Method

A. Generlization

Given Robot with a physical shape on two-dimensional perspective relative to the ground, this project try to convert the physical shape of the object to a combination of multiple circles like the figure illustrates below. These three circles are made according to the width of the rectangle will then be utilized as three coordinates in the following procedure; r is the estimated radius of each circle of the generalized structure corresponding to that point, and d is the estimated relative position of each points. For discussion convenience, these three dots are marked as a, b and c.

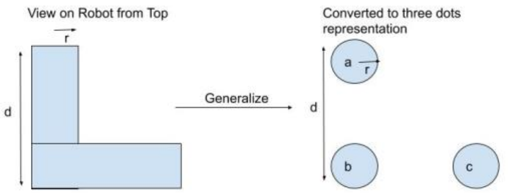

Fig. 1. A general representation of a L-shape robot using three circles representation

B. State Constraint

To completely represents the state of the L-robot, these three points will have a constraint as below.

1. a as a circle object should be able to reach b without collision
2. b as a circle object should be able to reach c without collision.

Then, this constraint is called C for convenience.

C. Multi-Points Sampling

The next step is traditionally following PRM algorithm by creating the sample map. In this case, this project uses the static joint point as a central point and generate the corresponding uniform random points on given map in the way Fig. 2 displayed below.

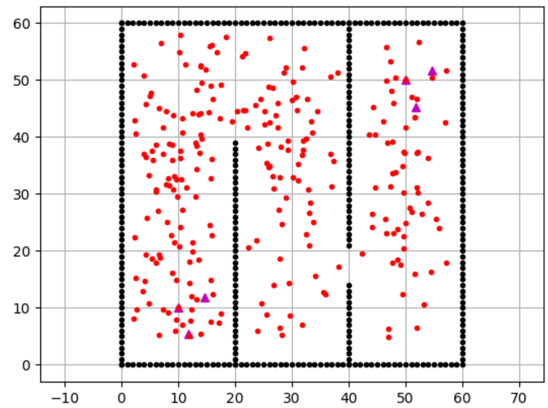

Fig. 2. The initialized sampling map, red dots is the sampled b points, the trianglular marker represents the initial position of three dots, which then show the state of the L-shape robot

Then, for each point generated above, another two points which corresponding to a and c will also be randomly generated given a random degree of rotating, and does not violate the physical constraint C. The newly generated sample is shown below.

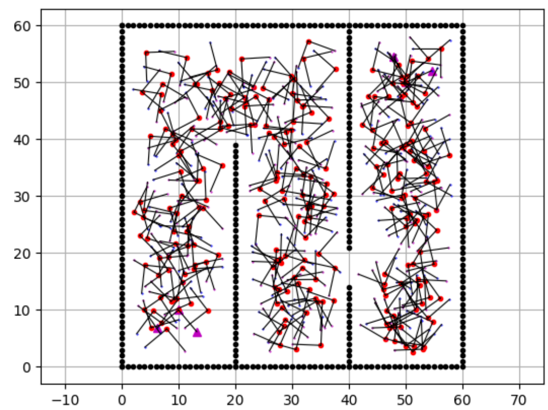

Fig. 3. The fully sampled graph, red dot is b, the blue tip on the edge is a, and the pink tip on another arm is c. The black line connects them to better illustrates that they represents the state of the robot.

D. RoadMap Generation

The next step to generating road map only for points b, which is a road map to the red dots. It will first treat points b with radius r and use local planning to check for collision. If any collision is detected, the branching will fail. Otherwise, this process checks its constraint with in C condition. If C constraint satisfied, there will be an extra trial test putted on it. The trial test will change the pose of the object until its C constraint is sufficed. If any trial test passed, which indicates there is a possible pose which allows the object to pass this step, the local planner moves on and test the next step. If not, the branching will fail.

In the L-shape Robot case, during the local planning if the branch points a or c hits obstacles. The trial test will try to rotate the object around center b points from 1 degree to 360 degree in 360 trials. If any one of these trials can make this object satisfy constraint C. The L-shape robot passed this step of local planning and moves on to the next step.

By repeating this procedure above, this process can assure that this object can pass to selected position without collision of its physical part.

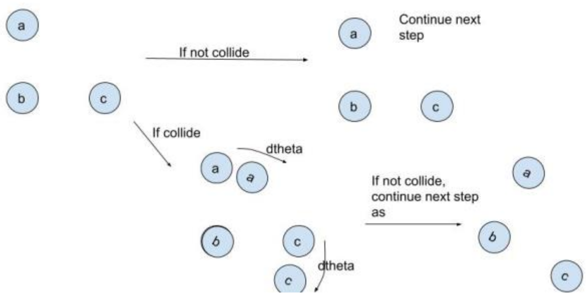

Fig. 4. An illustration of this process in graph

III. Experiments

This section will test on this algorithm with different parameters including edge length(he longest connectable distance), number of sampling points(the generated sampling points) and number of branch per node in road in different situations. These experiments are trying to explore the relationship between these parameters and it succeed rate. In all experiments, the L shape robot has r = 2 and d = 5(the distance between center a point and b point and center b to point c).

A. Given a Map with a Narrow "Door"

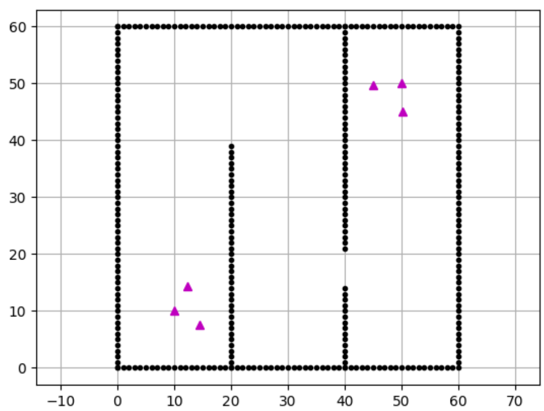

Fig. 5. An empty map with a narrow door at the end with width 5, which just almost fit the arm of the L-Shape robot, however, by traditional mean this object cannot directly pass the door .

Using this method with sampling points 1000, edge length 35 and 10 branching per node, the program receives a full roadmap below. For better illustration, all graph removes the supposed arm indicator between points in Fig.3. Thus, all nodes indicates the points b's position and all edges indicate moving between possible b's positions.

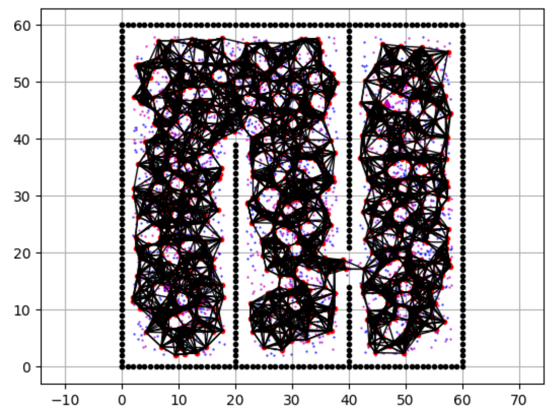

Fig. 6. A generated map with maxmum edge length 35, 1500 sampling points and 10 branching nodes.

If the program decreases the number of branching and number of sampling points to 5 and 500, the roadmap becomes much simpler. For illustration purpose, more experiments will be conducted in this case.

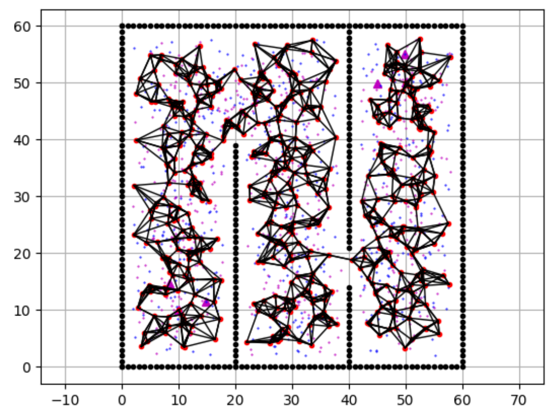

Fig. 7. A generated map with maxmum edge length 35, 500 sampling points and 5 branching nodes.

Moreover, decreasing edge length will increase the difficulty of mapping but supposedly help the precision of robot movement. If we decrease the edge length to 10, the graph is generated below. In this case, the difficulty of mapping means the possibility to generate a successful road map which can map the starting position to goal position illustration in Fig. 4.

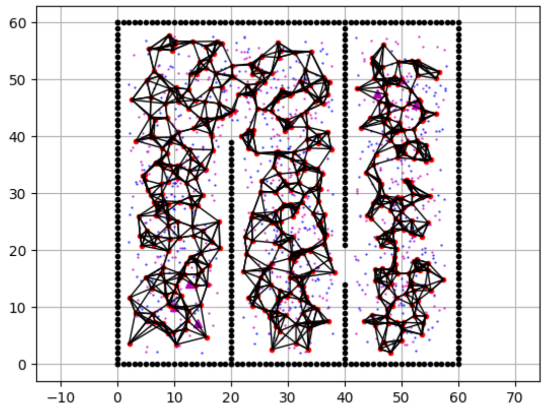

Fig. 8. A generated map with maxmum edge length 10, 500 sampling points and 5 branching nodes. Thie road map fails because it does not find the valid path from starting point to goal point.

One of the reason that low edge length decrease the possibility of succeed mapping is due to the nature of sampling can easily sampled farther from the door, which is the small gap at right side in Fig. 7. Given the low edge length, it is very rare that the sampled point will be able to connect through the other side of the door since both sides have points sampled farther away from the door.

Nevertheless, if the edge length is too high, the situation will be different.

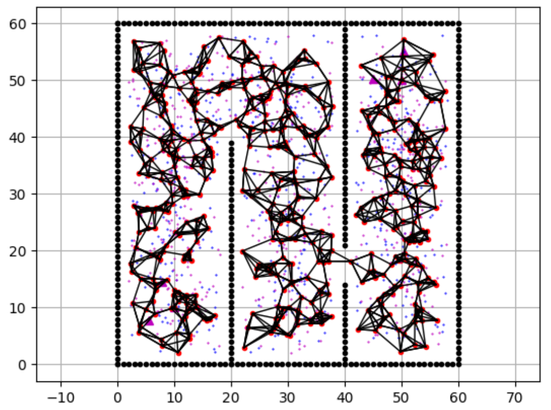

Fig. 9. A generated map with maxmum edge length 1000, 500 sampling points and 5 branching nodes. This will indicates that the node has a higher chance to attempt on connecting to legal point farther away from it, which increase the suceed chance that the point connected through the narrow door.

B. Given a Map with a Impassable Narrow Tunnel

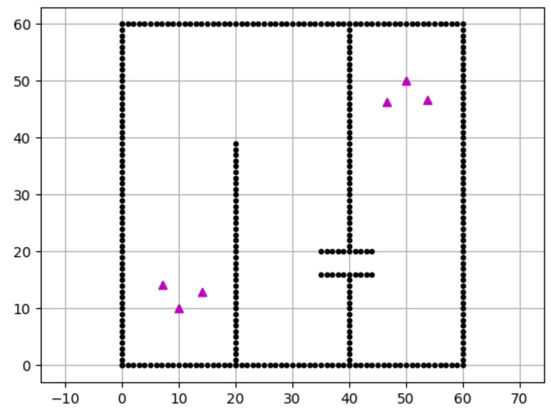

Fig. 10. An empty map with a narrow tunnel at the end with width 5, which just almost fit the arm of the L-Shape robot. It is clear that this object cannot pass the tunnel by any means. Thus, it is to illustrate the accuracy of the road map in incomplete situations.

Using this method with sampling points 1500, edge length 35 and 10 branching per node, the program receives a full roadmap below.

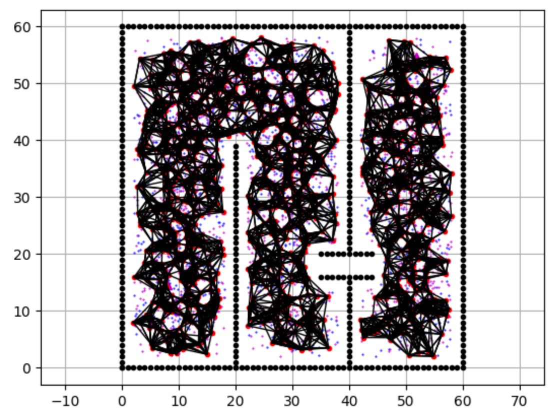

Fig. 11. A generated map with maxmum edge length 35, 1500 sampling points and 10 branching nodes.

Expected, the other road maps supposedly fails this situations.

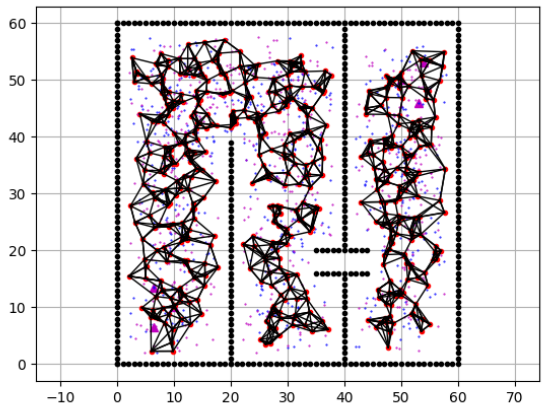

Fig. 12. A generated map with maxmum edge length 35, 500 sampling points and 5 branching nodes.

C. S-Shape Map with Two Narrow Passage

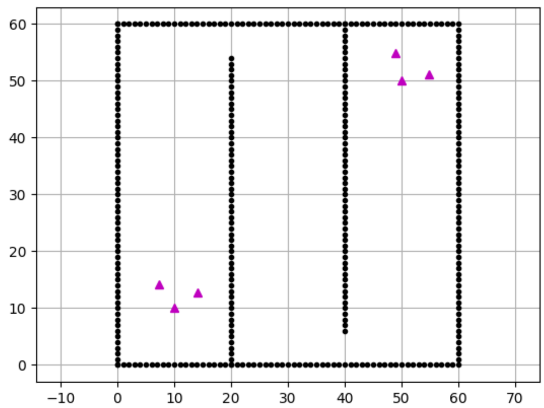

Fig. 13. The passage just almost fit the arm of the L-Shape robot, thus, by traditional mean this object cannot directly pass the door

This problem is proved extra difficult than the case showcased in Fig.4. The main reason is that due to the narrow passage is beside the wall, the random sampling cannot cover the optimal position very well. Thus, to counter this issue, in this experiment, the project increases the sampling points number from 1500 to 2000.

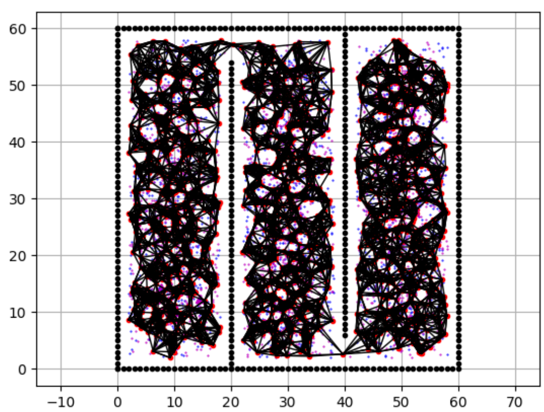

Fig.14. A generated map with maxmum edge length 35, 2000 sampling points and 10 branching nodes.

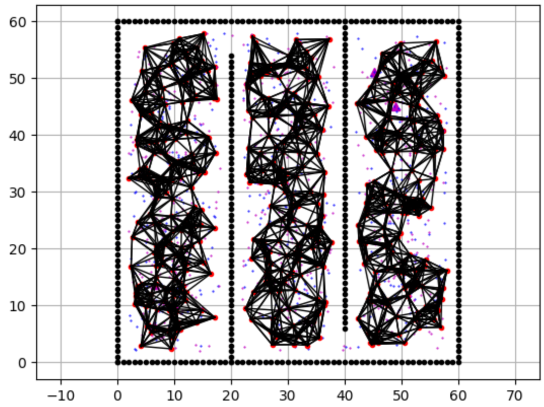

Fig. 15. A generated map with maxmum edge length 35, 500 sampling points and 10 branching nodes. This case failed due to not enough number of sampling points.

Unfortunately, even though increasing sampling points can reach failure. Thus, using a better algorithm such as OBPRM is more appropriate

IV. Conclusion and Discussion

According to above experiments, this method is proved to be able to solve L-shape robot planning problem with points generalization on the shape of robot. The major take out of this experiment is that during the local planning of the expanding phrase of road map. The object can test its constraint by different pose to search for a solution to fit through the narrow passage, which is a greedy but effective approach to solve this kind of problem. This project also shows that generalization on physical robot may simplify the problem during motion planning to special shaped robot. However, this method still has some drawbacks. First of all, this problem assumes that if the object can fit in perfectly during local planning, the object will not have a collision, and in reality, this may not be the case if the passage is specially formed in a way that object can fit in but cannot transform due to sealed environment. Secondly, this algorithm can still cause a missing narrow passage case due to the nature of random sampling of PRM, but this drawback can be overcome by sampling around obstacles. At last, this method only gives a general passage of the object, in this case is the b point of the L-shape robot, and the specified rotation of the robot is not marked out. This part may be implemented by the robot itself instead of the path planning part.