

Voronoi Diagram Based Roadmap Motion Planning

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Abstract—Robot Motion planning is one of the fundamental problem in robotics. It has various applications such as in Ware house automations, Driverless cars, Robotic surgery etc. The path planning problem is described as: to find a shortest or optimized path between start point and goal in a spatial configuration consists of obstacles of various types. There are many fundamentally different approaches suitable for different environmental configurations. The various methods are Cell Decomposition, Sampling method, Probabilistic Roadmap methods, Generalized Voronoi diagrams etc. In this project we will be exploring for Generalized voronoi diagrams in Robot motion planning.

I. RELATED WORK

A lot of research work is being done in the field of computation of Voronoi Diagram. Steven Fortune[1] has introduced a sweepline algorithm which can compute Voronoi Diagram for n point sites in $O(n \log n)$ time. This algorithm become famous as Fortune's algorithm. Paul Chew [2] presented "expanding wave" analogy for computing Voronoi Diagram based on convex distance functions. Colm [4] have extended this work to motion planning of disc amid polygonal obstacles with an algorithm of $O(n \log n)$ time complexity. A linear time algorithm for computation of Voronoi Diagram has also been introduced[3] for point sites lying on the vertices of convex polygon. However in our project we are using Matlab function 'voronoi' for computation of Voronoi Diagram for point sites which we are using in computing Voronoi Diagram for polygonal obstacles.

II. INTRODUCTION TO VORONOI DIAGRAM

Voronoi Diagrams: "A *Voronoi diagram of a set of sites in the plane is a collection of regions that divide up the plane. Each region corresponds to one of the sites and all the points in one region are closer to the site representing the region than to any other site.*" [6] The path generated by Voronoi diagram ensures minimum collision risk if any possible. Figure 1 shows voronoi diagram for point sites. Here we can see that all the points lying in the yellow region are nearest to the point site corresponding to yellow region.

The voronoi diagram for a line site can be generated by considering line as a linear array of point sites. Similarly Voronoi diagram of a polygonal object can be drawn by considering the polygon as a set of line segments. Figure 2 shows voronoi diagram of a triangle where first it is considered as a set of three line-segments then each line-segment is considered as a set of point sites.

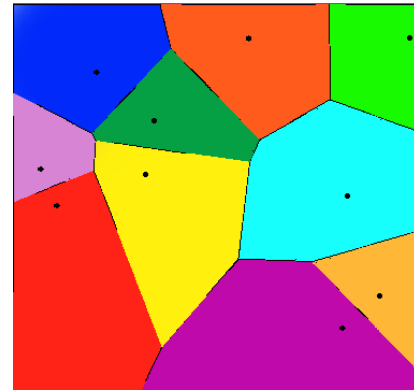


Fig. 1. Voronoi Diagram (Image courtesy [8])

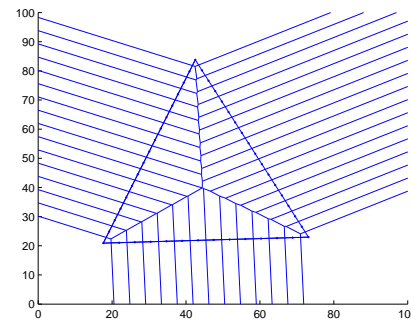


Fig. 2. Voronoi Diagram for Triangle by considering it as set of point sites

III. PROBLEM STATEMENT FORMULATION

In our problem statement an environment configuration consisting of polygonal obstacles with Start and Goal points is given. Our goal is to find the 'shortest' collision-free path from Start point to Goal point. For example a configuration is shown in figure 3 where there are two obstacles and Start point and Goal point are specified as green dot and red dot respectively.

Then our goal will be to find the 'shortest' collision free path from Start to Goal as shown in color magenta in figure 4. The green colored path shows the Voronoi Diagram for the given configuration. It is to be noted that the final path is a subset of Voronoi diagram.

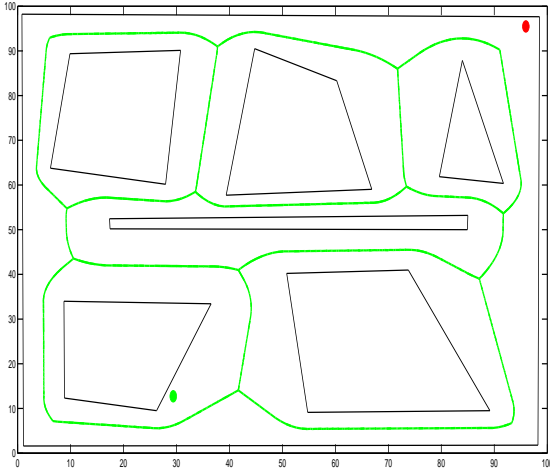


Fig. 7. Environment Configuration

After getting the Voronoi Diagram of the obstacle configuration. Our next task is to find the shortest possible route from Start and Goal. It is not necessary that Start and Goal lies on Voronoi Diagram. So for that we find the nearest Voronoi vertex from Start and Goal and named it Start' and Goal' respectively. The voronoi diagram can be represent in the form of acyclic Graph called Voronoi Graph. The weights in the adjacency matrix are the euclidean distances between the connected vertices. It is to be noted that Start' and Goal' both are Vertices of the Voronoi Graph. Now we can find shortest route between Start' and Goal' using any shortest route finding algorithm. We have used Dijkstra algorithm code by [7]. So using that algorithm we are able to get the final path from Start' to Goal'. Now combining the three paths Start to Start', Start' to Goal' and Goal' to Goal we can get final path from Start to Goal. Figure 8 shows the final path in magenta colour from Start (green dot) to Goal (red dot).

V. DESCRIPTION OF MATLAB FILES

There are 4 Matlab files in main project directory: `Obstacle_Draw.m`, `Get_Voronoi.m`, `Final_Path.m` and `dijkstra.m`. Using `Obstacle_Draw.m` any polygonal obstacle configuration can be drawn. For drawing obstacle `Obstacle_Draw.m` needs to be run first then a figure window will come. to draw an n-gonal object n-clicks at desired points should be made. After n clicks return keys needs to be pressed which confirms the drawing of that object. After pressing return key new object can be drawn. In `Obstacle_Draw.m` the number of object can be changed by changing value of parameter `Num_Object`. value of `Epsilon` can also be specified there. These configuration will be saved in `.mat`

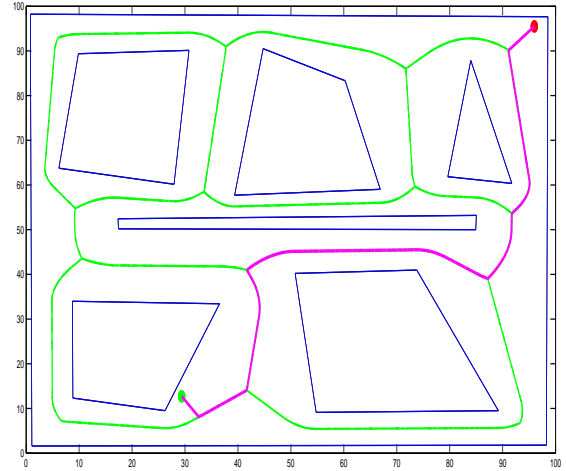


Fig. 8. Environment Configuration

file format in directory `Obstacle_Files` where the image of obstacle configuration corresponding to each `.mat` file is shown for reference. The filename can be changed by changing the string variable `FILE_NAME`. Now using `Get_Voronoi.m` any of the obstacle configuration can be loaded by specifying the filename stored in string variable `LOAD_FILE_NAME`. By running `Get_Voronoi.m` the Start and Goal points can be specified in the obstacle figure by two consecutive clicks after it Voronoi diagram for the obstacle configuration will be generated. After that, running `Final_Path.m` will give the path from Start to Goal.

VI. RESULTS AND CONCLUSION

Here in this work we are able to generate the final 'shortest-collision-free-path' using Voronoi Diagram for given obstacle configuration and start and goal points as seen from figure 8. This path is not always the shortest collision free path. In some configurations better shortest path which are collision free also exists. But in average sense our method gives results equivalent to shortest collision free paths.

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