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Motion Planning using Voronoi Diagram with Constraints

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Abstract— Motion planning is one of the challenging problem in the field of robotics. It has various applications in various fields such as computer graphics, climatology, ecology etc. Path planning is one of the essential component in navigation of robot. Path planning can be defined as finding an optimized collision free path from predefined source to destination. In this project, we formulate the path planning as: Given an environment having static obstacles, find a collision free path by using some constraints and concept of voronoi diagram. Our approach is to formulate the motion planning problem as simulation of static environment with obstacles and a system, and guide this system using voronoi diagram. A voronoi diagram of a set of points is a collection of regions that divide up the plane. Each region corresponds to one of the points, and all the points in one region are closer to the corresponding site than to any other site. In this framework, a voronoi diagram is created for a set of obstacles placed in a predefined workspace to estimate a path from a source to destination through the environment avoiding collisions with obstacles by following the constraints.

Keywords— Voronoi, Constraints, Simulation, Workspace, Obstacle

I. INTRODUCTION

The games industry is one of largest entertainment industry in the world. It mostly rely on realtime solutions which many times consists of path planning by objects.There are various techniques available for motion planning such as cell decomposition, Potential field, Roadmap etc. In our project we use voronoi diagram for constructing obstacle free path from a predefined source to destination. A voronoi diagram for a set of points is the partition of the plane in such a way that each point corresponds to one region and the voronoi edge so form is exactly in between two points that are consider at any instant .We demonstrate a framework where initially a set obstacles are given in a predefine workspace. Further we have to construct a voronoi diagram and by using this geometric structure and some constraints, the robot will be guided to find an optimal obstacle free path. Robot is a rigid body that is subjected to various obstacles and constraints. In our framework we define the constraints to guide the robots towards the planning goal. Constraints are classified into two categories: Hard constraints and Soft constraints. Hard constraints are the restrictions which must be followed in every situation. Soft constraints serves as a guide to or influence the objects in the scene to behave in a certain way. In our project, hard constraint is that the robot must always move within the predefined workspace and soft constraint is that it should always move towards the destination point or the goal point. In order to create a voronoi diagram, fortunes algorithm is used in this project. Further, we apply shortest path algorithm on it to analyze the path and find the most optimal collision free path. Now, the voronoi diagram and analyzed path along with the constraints will guide the robot to move from the given source towards destination. Section II defines the problem statement. Section III describes the related work. In section IV the stages followed in design and implementation are discuss. The section V shows the result ie. the implementation till date. Finally section VI describes a short conclusion of the project.

II. PROBLEM STATEMENT

The abilities within computerized simulation has achieved great heights in the last few decades. In this project, we referred to the domain of robotics in computerized simulation. The ultimate goal of this project is to design a framework for tracing path in predefined workspace which we refer to as static environment having obstacles in its way towards destination by using voronoi diagram and putting certain constraints or restrictions on it. These constraints guide the robot in moving towards the goal and finding a collision free path. Further the path must be an optimized path and in order to satisfy this, shortest path algorithm is used. The algorithm used for finding shortest path in this project is dijkestra algorithm.

III. LITERATURE REVIEW

There are various traditional techniques that were previously being used for motion planning. Some of them are discussed below along with their working and drawbacks.

A. Cell decomposition(CD)

Cell decomposition is a technique completely based on cells. A randomly created workspace is called a cell. The main objective of this technique is to provide a sequence of collision free cells from the starting point to the goal point. These obstacle free cells are called pure cells. They are added in the sequence. The cells containing obstacles are called corrupted cells or impure cells. These cells are further divided into two new cells. The pure ones are added in the sequence and the process continues. The cells represent the vertices and the boundary of the cells represents the edges of the graph. The start cell is considered as the start point and goal cell is considered as goal point or destination point [3].

Cell decomposition can be done in following three ways:

1) Exact cell decomposition
2) Approximate cell decomposition
3) Probabilistic cell decomposition

1) *Exact cell decomposition:* In this technique, the workspace is decomposed into convex polygons. The lines that connect centering points of cell boundaries are the path so formed.
2) *Approximate cell decomposition:* In this technique the workspace is divided to a grid within such a way that each cell in the grid represents a part of the workspace and each cell contains a flag that represents whether it has a free space or not.
3) *Probabilistic cell decomposition:* This technique is similar to approximate CD except that cells have a predefined shape and the cell boundaries do not represent any physical meaning.

B. Potential field (PF)

Potential field is a technique that uses two factors of forces such as force of attraction and force of repulsion. This could be understood as the goal having force of attraction and the obstacles having force of repulsion. This leads the robot towards the goal point (destination point). This technique is simple to implement. It provides complete freedom to choose the field function. The structure of PF algorithm is simple and it is easy to implement but it has a drawback. In situations where obstacles are located close to each other, the PF technique end up this kind of situation by moving between obstacles or causing local minimum problem. Later, these problems were modified but they were proved to be applicable to limited classes of objects and workspace[3].

C. Subgoal network (SN)

This technique uses a list of reachable configurations from the starting point to the goal point that is from source to destination. A study made by Chen and Hwang suggested a variation of subgoal network. The role of global planner was carried by the SN and the local planner was responsible for checking the reachabilities of subgoal. The switching between the local and global planning continues till the path is found or unless the sequence of subgoals are emptied. Chen and Hwang introduced motion planners based on a search strategy called Sandros.This strategy connects heuristically generated subgoal sequences using a local planner. Randomized motion planning based on SN was proposed by Glavina. The concept of subgrouping operations was introduced by Keshmiri and Payandeh for addressing dynamic environment. All these methods lack in adaptability and robustness. Moreover these methods were not suitable for dynamic environment.

D. Roadmap

This technique uses a map based approach. This map contains a set of paths where each path consists of collision free area connections. By following this approach, a network is constructed which is called a roadmap. Visibility graphs and voronoi graphs are two ways of implementing roadmap technique. The visibility graphs are constructed by connecting the start point (vertex), goal point and the obstacles between them. Using an visibility graph has an obvious advantage of finding shortest path as path planning problem. On the other side it has a disadvantage too. Since, the path is connected to the obstacles while achieving the shortest path it touches the vertices of the obstacles and sometimes even the edges hence it is not at all safe to use visibility graph. Voronoi Graphs on the other hand overcomes this problem [3].

Table below describes all the methods in short along with their workings and shortcomings:

Table I Methods previously used

	METHODS		
Sr. No.	***Method Name***	***Explanation***	***Drawbacks***
1	Cell decomposition (CD)	CD is a technique used to reduce the search space by using a representation based on cells. A sequence of collision free cells from starting point to the goal point is provided in this method. The collision free (obstacle free) cells are called pure cells. The cells containing obstacles (corrupted) are divided into two new cells and later the pure one (obstacle free) would be added to the collision-free path sequence. The start cell indicates the start point and goal cell indicates goal point. The sequence connecting start and goal cell is	Generating infeasible solution.

	METHODS		
Sr. No.	***Method Name***	***Explanation***	***Drawbacks***
		the path.	
2.	Potential Field (PF)	PF is a technique that uses the attraction and repulsion factors. This can be assumed as the goal having force of attraction that make the robot to move towards itself. On the other side the obstacles having force of repulsion that constantly make the robot to keep away from it.	Applicable to limited classes of object and configuration space.
3.	Subgoal network (SN)	The subgoal network is a method that uses a list of reachable configurations from the starting point to the goal point that is from source to destination. A variation of SN was proposed by Chen and Hwang in which a hierarchical path search was used. The role of global planner was carried by SN while a local planner was used to check the reachability of subgoals.	Lack of adaptiveness and robustness.
4.	Roadmap	In this technique a map is built that contains a set of paths where each path consists of collision free area connections. Following this approach, a network is constructed. This network is called roadmap. This method enables finding of the shortest path as motion planning or path planning using connected networks which is called roadmap.	1.The method is inefficient in a densely populated environment. 2. Robots safety would be in danger due to possibility of collision with obstacles.

IV. DESIGN AND IMPLEMENTATION

The design of a system produces the details that states how a system meets the requirement. The design of this project is divided into following two stages:

A. Creation of Voronoi diagram.
B. Path detection and Path planning.

Initially, only the predefined workspace and set of points that refer to obstacles are given as shown in the figure below.

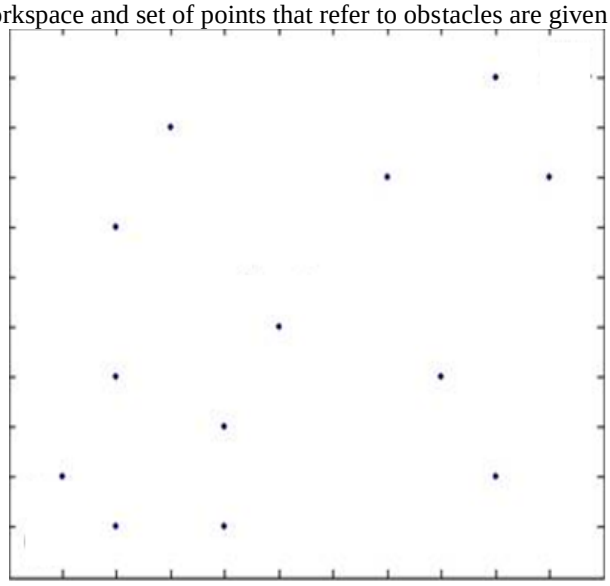

Fig. 1 Workspace creation of voronoi diagram

B. Creation of voronoi diagram

Voronoi diagram is created by using Fortune's algorithm. Fortune's algorithm uses sweep line algorithm for generating voronoi diagram from a set of points in a plane. It uses the concept of sweep line as well as the beach line. Sweep line is

an imaginary line assumed to be vertical that moves from left to right throughout the workspace. All the points to the left of the voronoi diagram are the points that are already considered and the points to the right are the one to be consider. The beach line is not exactly a line but a parabolic structure that follows the sweep line forming the voronoi edges where the two parabolas intersect each other. It was originally published by Steven fortune's in 1986. It creates voronoi diagram in such a way that the points are equidistance from the voronoi edges. In the figure shown below, the green points indicate the start and the goal point. The green point at the bottom indicates the source and that at the top indicates the goal point (destination point).

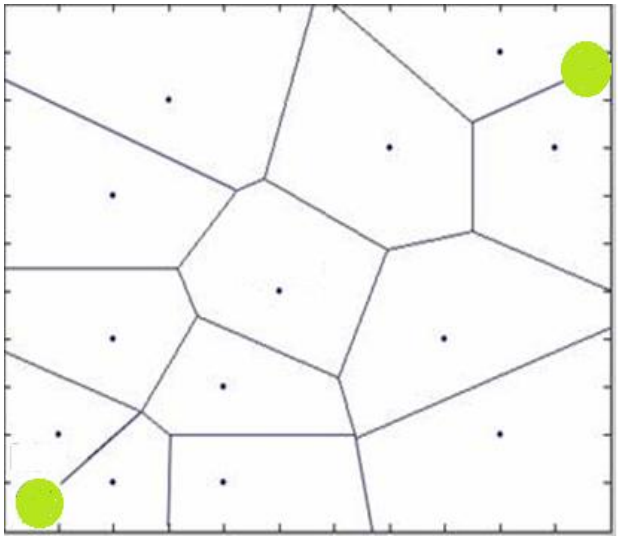

Fig. 2 Workspace after creation of voronoi diagram

C. Path planning

Path planning is an ability to find a path free of obstacles from initial position to given final position. Initial position can be referred as the source point and final position can be referred as the destination point or the goal point. The path planning is based on voronoi diagram where the generated points in the given predefined workspace are considered as obstacles and voronoi diagram is created ,later intersection points and the edges of voronoi diagram are use to guide the object(robot) in path analyzing. Path planning is done with the help of shortest path algorithm.

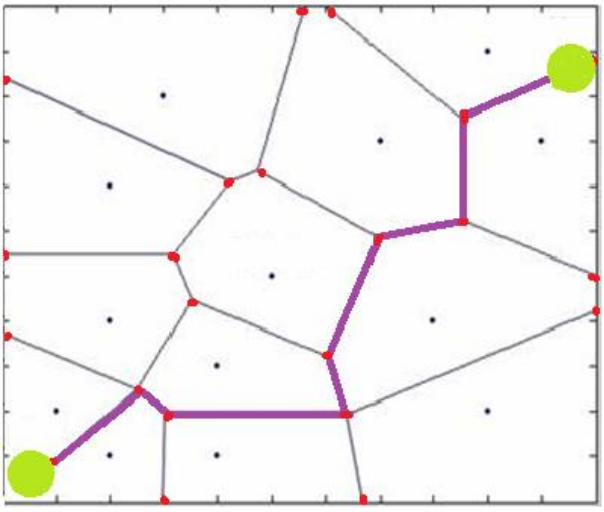

Fig. 3 Workspace after path analyization

In the figure above, the red points indicates the intersection points of the edges of the voronoi diagram which are referred as the nodes of voronoi diagram and the purple line indicates the analyzed shortest path after applying the shortest path algorithm on it. The points indicates the obstacles, the robot has to move on the purple line as it is the analyzed shortest path.

V. RESULT

The figure below shows the demonstration of the implementation till date. The points in the fig. 4 are referred as the obstacles .These points are selected from the given list consisting number of points. User can pick one option at a time from the list. For eg. in the fig. below, 7 is selected. These points get generated on the workspace. After generation of points in the given workspace, the draw voronoi button is need to be click. Once this button is click the voronoi diagram is created on the given workspace using Fortune's algorithm. The voronoi diagram so created is referred as path. If the user wants to select points next time it should be selected only after clearing the workspace by using clear button.

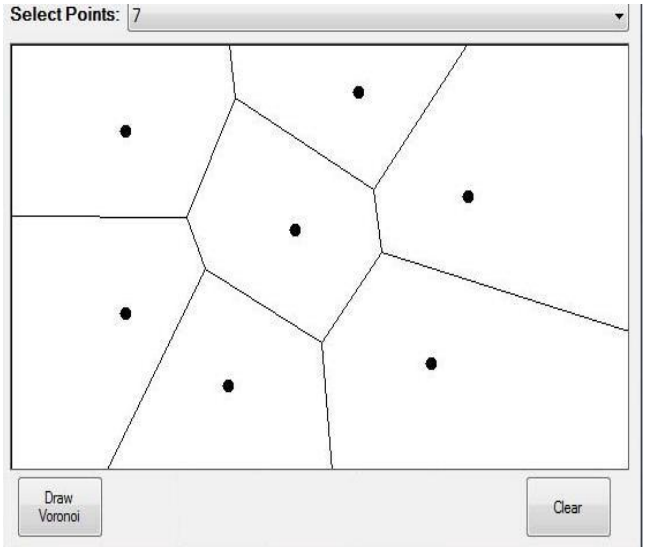

Fig. 4 Result of implementation till date

VI. CONCLUSION

In this paper, we demonstrate a framework to perform path planning in static environment (workspace) and from the study on different methods we have concluded that though there are various methods available for path planning in static environment but there is a need to develop new technique that will result in formation of more optimal and collision free path by using different attributes such as path length, computation time in static workspace with the use of graphical representation such as voronoi diagrams. Voronoi diagram is a strong geometrical structure for representing static environment and with this we can easily generates collision free paths.

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