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Path planning algorithm for cluttered
environments using computational
geometry approaches

Project Report

Submitted by
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ME18B074

in partial fulfillment of requirements
for the award of the dual degree of

BACHELOR OF TECHNOLOGY in
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and

MASTER OF TECHNOLOGY in
ROBOTICS

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CERTIFICATE

This is to certify that the project titled Path Planning algorithms for cluttered environments using computational geometry approaches submitted by Shreyash Patidar (ME18B074) to the Indian Institute of Technology, Madras, for the award of the degree of Bachelor of Technology in Mechanical Engineering and Master of Technology in Robotics, is a bonafide record of the research work done by him under our supervision. The **contents of this thesis, in full or in parts, have not been submitted to any other Institute or** University for the award of any degree or diploma.

Shreyash Patidar
Prof. M. Ramanathan (ME18B074)

Name of Guide: Name of student

Signature: Signature

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ABSTRACT

KEYWORDS: Path Planning, Computational Geometry, Voronoi Diagram, 3D environment

Path planning is one of the most crucial technologies that make a robotic agent take decisions autonomously. However, Path planning by computational geometry means is not so frequently visited topic. This project work involves developing a new algorithm for robotic Path Planning using Computational Geometry approaches. There are existing algorithms in the field of Path Planning. Some of them decompose obstacle course into a grid of evenly sized cells and others consider the geometry of each obstacle. Optimization methods and search algorithms are applied to it to find the best possible paths. There is a well-known issue with geometry-based algorithms and their computational complexity. At the same time, it can generate results with little to no approximations. This work is an effort to crack a balance between these approximations and complexity. This algorithm approximates obstacles as ellipses, runs nearest-neighbors tests to get Voronoi diagram-like results, and runs path search

traversals to find optimal paths. As the algorithm focuses more on geometry, the algorithm will find its use in cluttered environments or in places where obstacle geometry is of the order of size of the robotic agent and obstacle geometry plays a crucial role. And the approximations as ellipses will boost the speed manifold. Parametric representation of ellipses will bring down tangent computation complexities from order 3 and 4 to constant time operations. Similarly, it'll bring down complexities in the path search and optimization step. Some uses-cases of the algorithm can include robots navigating busy streets and moving packages in small-scale, unorganized warehouses. Later the algorithm can be extended for 3D environments(it is a part of the project timeline) where it will find use in planning missions for underwater caves, low-height search operations for drones, simulating machine movements for rescue operations, and operations in tight spaces like mines.

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CHAPTER 1

INTRODUCTION

Path planning is one of the most crucial technologies that make a robotic agent take decisions autonomously. It is a way of finding the best suitable paths for a robotic agent. The simplest problem involves finding the path for a point object in the obstacle course. The more involved ones deal with finding the orientations and actions that the agent should perform to reach its goal pose.

This project work involves designing a new data structure to represent nodes and obstacles, and building graphs to handle obstacles in the cluttered environment more efficiently. The aim is to exploit the concepts of Computational Geometry to handle the geometry of obstacles more effectively, and at the same time use elliptical approximations to address the problem of higher Complexity of Geometry based path planning algorithms.

1.1 Background

The work started with understanding existing geometry-based algorithms and especially the Voronoi diagram-based algorithm. It was followed by experimenting with data structures, checks, and conditions and ultimately shaping into a new algorithm. This algorithm starts with approximating the obstacles as ellipses (based on the order of accuracy). Internal tangents or non-extreme tangents between each pair of ellipses are used to identify the nearest neighbors of each elliptical obstacle. For each pair of these nearest neighbors, a quadrilateral unit is defined in which one pair of opposite sides are the chords of ellipses and the other pair of opposite sides can be used by the robotic agent to enter or exit these quadrilateral regions. The obstacle course is then represented in terms of these quadrilateral units. Graph search algorithms are then used to find paths in terms of these quadrilateral units.

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