

Point in polygon calculation using vector geometric methods with application to geospatial data.

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Abstract

In this work, we designed algorithms for the point in polygon problem based on the ray casting algorithm using equations from vector geometry. The algorithms were implemented using the python programming language. We tested the algorithm against the point in polygon algorithms used by the shapely (and by extension geopandas) library and the OpenCV library using points from the google Open Buildings project. Our algorithm in pure python performed much better than the shapely implementation. It also performed better than the OpenCV implementation when combined with the Numba optimization library. We also performed simulations to verify that our algorithm performance was of the order $\mathcal{O}(n)$.

Keywords— point in polygon, ray casting, vector geometry, shapely, Numba

Introduction

The point in polygon problem is a fundamental geometric problem with a wide range of applications in computer graphics, painting simulation, robotics, geosciences, remote sensing, and geographic information systems. Therefore, efficient numerical algorithms for solving point in polygon computations are essential.

Many algorithms have been proposed (for instance in [7, 5, 10, 2, 8, 6]). Some of the methods include the winding number method [7, 10, 2, 6], which measures the number of times a polygon encloses a point, the sum of angles method [8, 6], where the sum of the interior angles of the polygon is used, and the ray casting method [8, 5]. The ray casting method involves shooting a ray from the point in question in any direction and counting how many times the ray intersects the boundaries of the polygon. Most of these methods assume the polygon is convex.

Several of the algorithms are computationally expensive and are sensitive to rounding and truncation errors. [6] states that the time complexities of the preprocessing step ranges from $\mathcal{O}(n)$ to $\mathcal{O}(n^2)$. In this paper, we design an algorithm for point in polygon computation using vector geometric methods, with the advantage that the algorithm can take advantage of processor parallelization.

The work is broken down in the following sections: The method section where we develop our algorithm from the vector geometric definition of the line. In the implementation section, we write the python code for the algorithm developed in methods then in the simulation section we test the algorithm on real world data and against other algorithms.

Method

Our proposed algorithm is based on the ray casting method. Suppose we want to determine whether a point $P(x, y)$ lies within a closed polygon R with vertices R_0, R_1, \dots, R_n , where $R_0 = R_n$. In the ray casting method, a ray l is drawn moving out from the point P in a specific direction. The point P lies inside the polygon R if l intersects the edges of R an odd number of times. In vector geometry, one way of writing out the equation of a line is the normal form. Let n be a normal vector to the line. Note that a line in the 2D plane has two normals going in opposite

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Table of Contents Geometric Methods In Biomedical Image Processing

1. Understanding the eBook Geometric Methods In Biomedical Image Processing
 - The Rise of Digital Reading Geometric Methods In Biomedical Image Processing
 - Advantages of eBooks Over Traditional Books
2. Identifying Geometric Methods In Biomedical Image Processing
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an eBook Platform
 - User-Friendly Interface
4. Exploring eBook Recommendations from Geometric Methods In Biomedical Image Processing
 - Personalized Recommendations
 - eBook User Reviews and Ratings
 - eBook Bestseller Lists
5. Accessing Geometric Methods In Biomedical Image Processing Free and Paid eBooks
 - eBook Public Domain eBooks
 - eBook Subscription Services
 - eBook Budget-Friendly Options
6. Navigating eBook Formats
 - ePub, PDF, MOBI, and More
 - eBook Compatibility with Devices
 - eBook Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of eBook
 - Highlighting and Note-Taking eBook
 - Interactive Elements eBook

8. Staying Engaged with Geometric Methods In Biomedical Image Procebing
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Geometric Methods In Biomedical Image Procebing
9. Balancing eBooks and Physical Books Geometric Methods In Biomedical Image Procebing
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Geometric Methods In Biomedical Image Procebing
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Geometric Methods In Biomedical Image Procebing
 - Setting Reading Goals Geometric Methods In Biomedical Image Procebing
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Geometric Methods In Biomedical Image Procebing
 - Fact-Checking eBook Content of Geometric Methods In Biomedical Image Procebing
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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