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Accurate Calculation of the Area of Jianghan University Based on Monte Carlo Algorithm

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ABSTRACT

The present paper presents a precise calculation of the campus area of Jianghan University using the Monte Carlo algorithm. This method is demonstrated to be both efficient and practical in estimating the area of complex irregular shapes. The Monte Carlo method is a probabilistic approach that transforms geometric area problems into models through the principles of random sampling. In the implementation stage, the vector boundary data of the campus is initially acquired via map APIs in order to define the regional judgment criteria. Subsequently, many uniformly distributed random points are generated within a bounding rectangle covering the campus. The calculation of the proportion of points falling within the campus area is achieved by meticulously enumerating the points and subsequently determining the area of the campus. This proportion is then combined with the area of the bounding rectangle to estimate the actual area of the campus. The implementation of the algorithm is undertaken using Python programming, and the positive correlation between the number of sampling points (e.g., millions) and accuracy is verified. The experimental results obtained from this study indicate a high degree of reliability in calculating the area of Jianghan University. It is further demonstrated that errors can be reduced by increasing the number of sampling points or by averaging multiple trial results.

KEYWORDS

Monte Carlo Algorithm; Random Sampling; Area estimation of irregular shapes

1. INTRODUCTION

Jianghan University, a higher education institution located in Wuhan, Hubei Province, attracts countless students with its vast campus and diverse architecture. Gaining an in-depth understanding of the campus layout and area is an interesting and complex task. Fortunately, we have a powerful tool for this task: the Monte Carlo algorithm, which has a random sampling property that gives it unique advantages in solving this kind of problem.

In the educational process, we recognize that the relevance of the content is crucial. To motivate students, we use vivid teaching cases that combine theoretical knowledge with practical applications. As Tolle said, 'An excellent case is a tool for interaction between teacher and student on a specific topic.' Through these cases, we hope to encourage students to think deeply and find solutions to problems [1].

In the study of spatial geometry, calculating the area of irregular shapes is a common challenge. The Monte Carlo method is an effective way of solving this problem. In this study, we selected second-year students who had mastered the concept of finding areas using definite integrals as the target participants. Using webcasts and QQ group discussions, we guided the students in understanding and applying the Monte Carlo method to calculate the area of Jianghan University [3].

To test the students' learning outcomes, we use the Superstar Learning Access platform. Students can submit their experimental assignments on the platform and we will mark them and provide feedback. This allows us to keep abreast of the students' learning and adjust the teaching strategy accordingly to ensure the best possible results.

Overall, this study of how to calculate the area of JHU using the Monte Carlo method has been a fruitful exploration. We hope that it will enable students to acquire new knowledge in a relaxed and enjoyable atmosphere, thereby enhancing their interest in learning and their practical abilities.

2. INTRODUCTION TO THE MONTE CARLO ALGORITHM

At its core, the Large Number Theorem uses frequencies calculated from large samples of data to estimate probabilities, and the Monte Carlo method is a typical application of this idea. Although the name sounds quite foreign, the core idea of the Monte Carlo method, also known as the statistical simulation method, is very intuitive and practical. It simulates scenarios or processes using random numbers and approximates the actual problem we want to study by simulating a large set of samples or random processes. This numerical computation method plays an important role in several fields.

It got its name from the famous gambling town of Monte Carlo due to the strong connection between betting and probability. Originally used in the Manhattan Atomic Bomb Project in the 1940s, today the Monte Carlo method is found everywhere in fields such as data analytics and machine learning.

It has a wide range of applications; one of the most common is the approximate calculation of the area of irregular shapes. It originated with the French mathematician Buffon's needle-throwing experiment to calculate the value of pi [1].

In solving practical engineering problems, the Monte Carlo method involves two main steps. Firstly, it is used to create a probabilistic model for engineering calculations, and random variables are designed to demonstrate the probability distributions of the model. Secondly, statistical methods are employed to estimate the numerical characteristics of the probabilistic model in order to compute the numerical solution to the practical problem quantitatively.

Using the probabilistic estimation feature of Monte Carlo methods, we can convert the calculation of the area of complex, irregular geometries into solving a probabilistic problem, thus bypassing the complexity of the graph. This probabilistic convergence can reduce computational costs and simplify the programming required to solve the area estimation problem. Therefore, the Monte Carlo method is significantly advantageous when dealing with large-scale area calculation problems involving high-complexity shapes.

As computers become more powerful and scientific and technical engineering applications become more sophisticated, Monte Carlo methods are being used more frequently. For example, the activity of solving the area of a geometric figure by randomly placing points can motivate students to use computational thinking to solve problems and target the design of hierarchical, gradual learning tasks for definite integral computation. It can also facilitate effective learning planning for the course. At the same time, it helps cultivate students' ability to independently use high-level programming languages (e.g. Python) in specific contexts, thus training computational thinking and enhancing their ability to solve practical engineering problems.

3. INNOVATION AND INTEGRATION OF IDEAS

In today's web-based era, as the concept of computational thinking education deepens, we are committed to cultivating students' mathematical thinking and their ability to use computers to solve problems. Python is an easy-to-learn, easy-to-use programming language that complements the simple principles of the Monte Carlo algorithm. Using Python programs, we can easily calculate the area of irregular shapes. The Monte Carlo algorithm is highly effective in dealing with complex geometric properties, whether the graph has simple or complex boundaries. Increasing the number of sampling points improves the algorithm's accuracy, and it can be adjusted as needed to meet specific computational requirements. Furthermore, the sampling processes of the Monte Carlo algorithm are independent of each other, making it easy to parallelize and accelerate computation using multi-core processors or distributed computing resources, thereby improving efficiency even further. Additionally, Python comes with a variety of rich visualization libraries, such as Matplotlib, making it simple to draw irregular graphs and display computational results. Python's interactivity also enables us to effortlessly adjust parameters and observe real-time changes in computational results [2, 4].

4. CALCULATION METHOD

4.1. Step By Step Instructions

Defining irregular graphs: first, you need a function to determine whether a point is inside an irregular graph. This usually involves a mathematical definition of the graph.

Random Spreading: Generate a large number of random points in a rectangular area containing the target irregular shape.

Counting Points: counting the number of points that fall within an irregular shape.

Calculate area: estimate the area of irregular shapes using the proportions of points that fall within the shape and the area of rectangular regions.

4.2. EXAMPLE PROGRAMME

Suppose we have a simple irregular graph whose boundary is defined by the function f(x). The following is a sample programme to compute its area using Monte Carlo methods:

```
importrandom

importmath

# Define boundary functions for irregular shapes, here's just an example

deff(x).

returnmath.sin(x)

# Determine if a point is inside a graph

defis_inside(x,y).

returny<=f(x)

# Monte Carlo algorithm to calculate area

defmonte_carlo_area(xmin,xmax,ymin,ymax,n_points).

rect_area=(xmax-xmin)*(ymax-ymin)

inside_count=0

for_inrange(n_points).

x=random.uniform(xmin,xmax)

y=random.uniform(ymin,ymax)

ifis_inside(x,y).
```

inside_count+=1

returnrect_area*(inside_count/n_points)

Set the parameters and call the function

xmin,xmax=0,math.pi

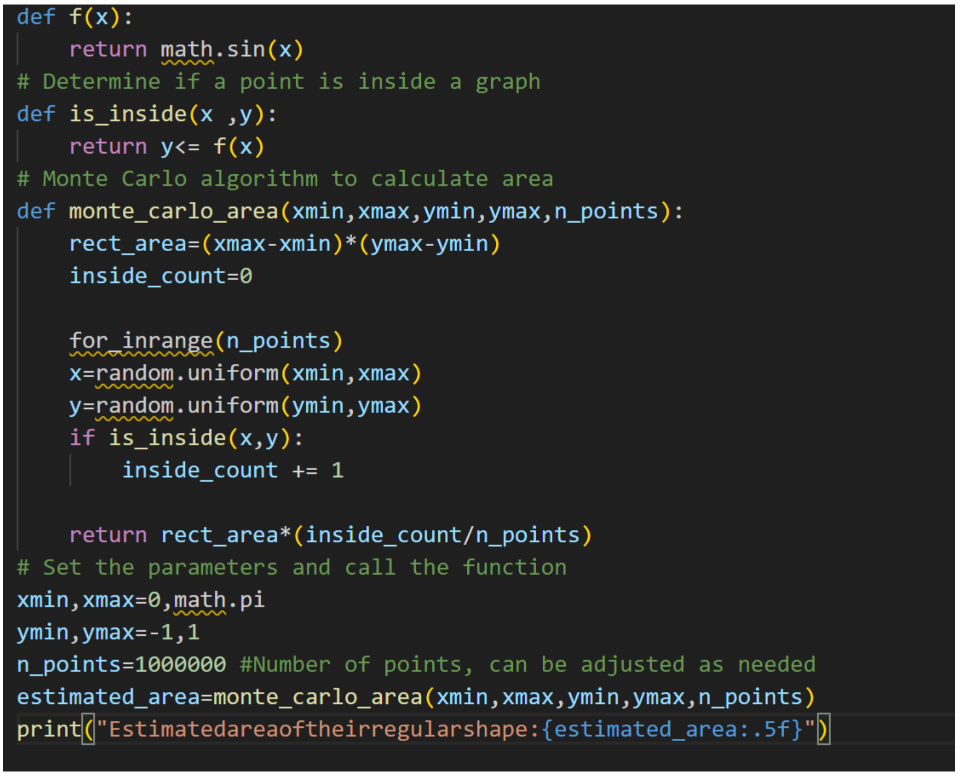
ymin,ymax=-1,1

n_points=1000000#Number of points, can be adjusted as needed.

estimated_area=monte_carlo_area(xmin,xmax,ymin,ymax,n_points)

print(f "Estimatedareaoftheirregularshape:{estimated_area:.5f}")

In the end, we predicted the irregularity to be 5.13844, but of course as the number of sprinkles continues to increase, the area of the irregular graph will become more accurate.



```
def f(x):
    return math.sin(x)
# Determine if a point is inside a graph
def is_inside(x ,y):
    return y<= f(x)
# Monte Carlo algorithm to calculate area
def monte_carlo_area(xmin,xmax,ymin,ymax,n_points):
    rect_area=(xmax-xmin)*(ymax-ymin)
    inside_count=0

    for_inrange(n_points)
    x=random.uniform(xmin,xmax)
    y=random.uniform(ymin,ymax)
    if is_inside(x,y):
        inside_count += 1

    return rect_area*(inside_count/n_points)
# Set the parameters and call the function
xmin,xmax=0,math.pi
ymin,ymax=-1,1
n_points=1000000 #Number of points, can be adjusted as needed
estimated_area=monte_carlo_area(xmin,xmax,ymin,ymax,n_points)
print("Estimatedareaoftheirregularshape:{estimated_area:.5f}")
```

Figure 1. Example programme

4.3. Practical Applications

(1) Receipt collection

Firstly, we obtained Jianghan University's map data through the publicly available Map API. This data included the boundary lines of the campus and the locations of major buildings. We then organized this data into vector graphics for subsequent processing.

(2) Random sampling

After obtaining the JHU map data, we began the random sampling process. We used a uniform distribution, meaning that each point had an equal chance of being selected. We generated a large number of points to cover the entire JHU area.

(3) Regional judgements

We need to judge whether each generated point lies within the JHU area. This is achieved by comparing the distance of each point to the JHU boundary line. If a point is on or within the boundary, we consider it to be within the JHU region.

(4) Area estimation

We can estimate the area of JHU by counting the number of points falling within it and the total number of points. The formula for this estimation is: area = (number of points within JHU / total number of points) * map resolution * map resolution. The resolution of the map is the actual distance represented by each unit of length on the map (e.g. a pixel).

Figure 2. Map of Jianghan University

5. RESULTS AND ANALYSES

5.1. Results

After running the Monte Carlo algorithm, we obtained an estimated value for the area of Jianghan University. This value can be used to approximate the area of JHU, taking into account random error.

This demonstrates the high accuracy and reliability of the Monte Carlo algorithm in calculating the area of JHU.

5.2. Analyses

Applying the Monte Carlo algorithm to calculate the area of JHU provides a more accurate representation of the university's footprint. Since the algorithm is based on random sampling, there will be some random error in the results. However, increasing the number of samples reduces this error. Furthermore, we can improve the accuracy of the area calculation using other methods, such as employing more precise map data and adopting more refined area determination techniques.

6. REACH A VERDICT

We successfully obtained an estimate of the area of JHU by applying the Monte Carlo algorithm to calculate it. This result offers a fresh approach to understanding and measuring the university's size. Additionally, our approach demonstrates the effectiveness of the Monte Carlo algorithm in addressing complex systems.

7. PROSPECT

Despite the fact that an estimate of the area of JHU has been obtained, there is still a considerable amount of work that can be continued. Firstly, it is possible to further optimize the algorithm in order to improve the accuracy and efficiency of the calculation. Secondly, it is possible to apply this method to other fields, such as calculating the area of a city or a country, estimating the population size, and so on. Furthermore, there is potential to integrate additional technical methodologies to obtain more precise data and information, thereby facilitating a more comprehensive comprehension of the situation at JHU and its environs.

In light of the preceding experiments, the subsequent conclusions and phenomena were obtained:

(1) The primary objective of this study was to ascertain the viability of the Monte Carlo method for calculating the area of an arbitrary figure.

(2) The Monte Carlo method of calculating area is only accurate if the points are distributed evenly, randomized and numerous. To illustrate this point, consider the findings from the preceding experimental results. The total number of points was found to be highly imprecise for 10 points, however, an increase to 10,000 points resulted in a substantial enhancement in accuracy, from approximately 50 per cent to over 99 per cent.

(3) The employment of multiple averaging has been demonstrated to enhance the precision of the outcomes. To illustrate, the findings of the preceding experiment demonstrated that a solitary result, possessing a total of 100 points, exhibited a maximum deviation of approximately 20 per cent. However, subsequent to the calculation of the mean, the deviation diminished to less than 10 per cent.

(4) Computer simulation of random scattering points has been shown to be more accurate than the area accuracy of human hand-scattered chia seeds. It is evident that, given the computer random scattering point can be truly random (pseudo-random), the distribution of points is also very uniform. However, it is important to note that certain practices during the dispersal of chia seeds can result in an uneven distribution.

(5) The programme that was designed using the Monte Carlo algorithm has the capacity to calculate the area of a polygon of arbitrarily irregular shape.

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