Information (PEAK)

December 24, 2024

Final project assignments

Due: Noon, January 7th

Uchida Kaoru

Project / assignment outputs

1. Write a report and submit to UTOL
   - Main part in a single pdf file with helpful screenshots
   - For each problem, try to write a self-contained report consisting of:
     1. Problem setting with your interpretation
     2. Base idea of your approach, algorithm and implementation
     3. Run results to show that you solved
   - Optionally (for extra points): include observations, further study, and your subjective comments
2. Additional points for a short presentation (as usual)
   - Brief summary of your idea and its originality
   - Effective and appealing demonstration

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Ethics – **No plagiarism**

- ✓ Plagiarism: “An act of fraud which involves both stealing someone else’s work and lying about it afterwards” (- www.plagiarism.org)

- ✓ If you turn in the work of someone else (including any generative AI) as your own, without understanding what is going on, you have committed plagiarism

- ✓ If you want to use AI tools as your studying assistant, do NOT just “copy and paste,” but be sure to understand the logic, algorithm, and implementation of the proposed solution, so that you can explain the details and modify the code yourself.

Final project -- Problem 1

Numerical root finding and visualization

1. Plot the graph of $f(x) = x^3 + \ln(x)$ for $0 < x < 2$.
2. Find the root of $f(x) = 0$ using the bisection method. Then visualize the iteration vs. absolute error relation.
3. Do the same with the Newton-Raphson method.
4. Provide a comparative analysis of the performance of the both methods.

Final project -- Problem 2

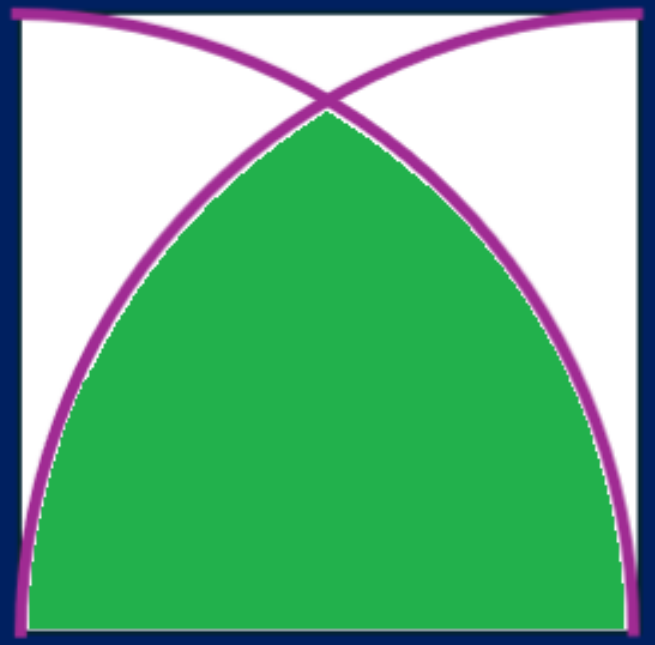
Letter frequencies and entropy

1. Determine the relative occurrence frequency of each alphabet letter in the given dictionary file (worddic.txt), sorted in descending order.
2. Create a histogram of the above.
3. Assuming the actual occurrence frequency of letters is the same as above, calculate the average information (entropy) per character.
4. Identify the frequency distribution that maximizes the average information; and calculate the average information in this case.

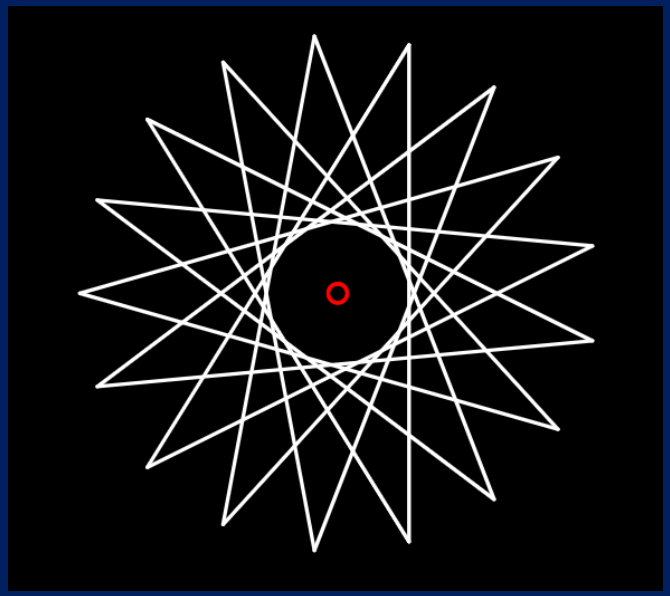
Final project -- Problem 3

Monte Carlo method

1. In the figure, two quarter-circle arcs with a radius of 1 are drawn inside a square with a side length of 1. Estimate the area of the green region using the Monte Carlo method.
2. Calculate it mathematically and compare the results.



Final project -- Problem 4



Spiky flower

This figure is created by connecting every *k*-th vertex of an invisible regular *n*-sided polygon.

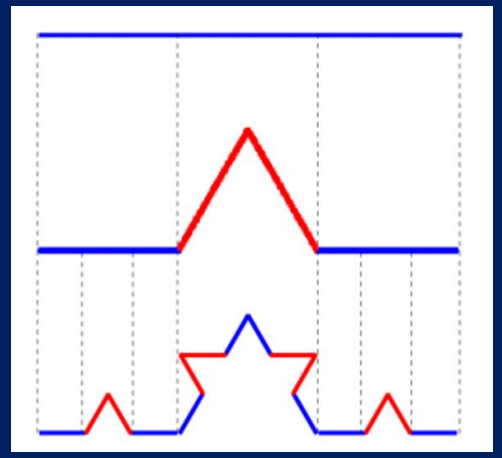
1. Draw the same figure, ensuring the central red circle is included.
2. Analyze how the size and shape of the inner white polygon (formed outside the red circle) depend on the parameters *n* and *k*. Document your observations, providing mathematical reasoning to explain the relationships.

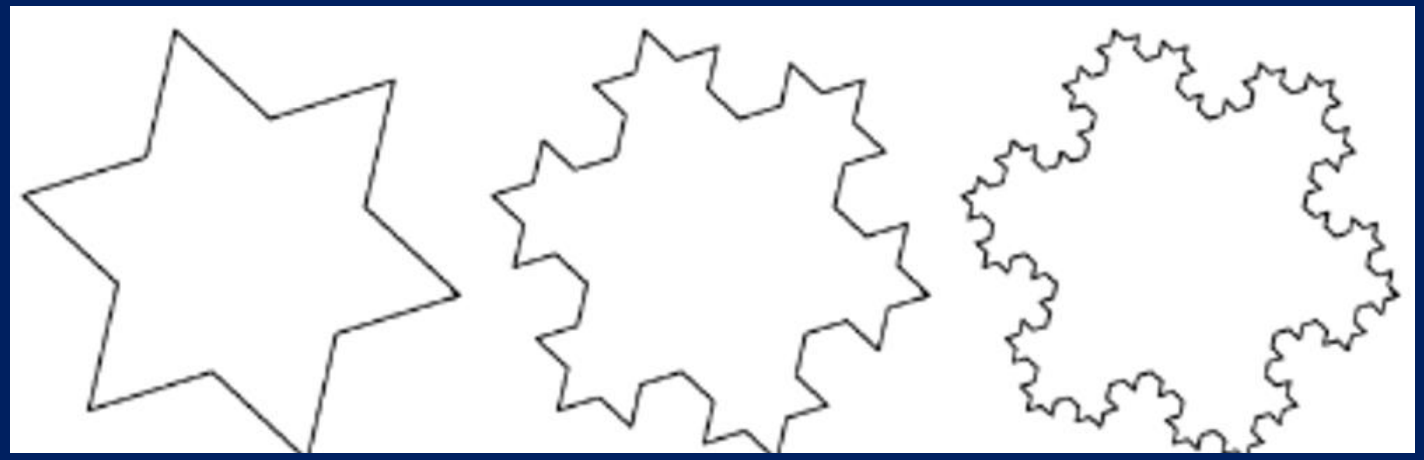
Final project -- Problem 5

Koch snowflake

Koch curve of level 0 is a straight line, and level 1 is constructed by replacing its middle 1/3 segment by the two segments of the same length, forming a "spike" (left figure). Likewise, level *(n+1)* curve is constructed by applying this transformation to each of the all segments of a level *n* curve.

1. Define a recursive function to draw a Koch curve of level *n*.
2. Draw a Koch snowflake of level *n* by arranging three Koch curves of the same level into the shape of an equilateral triangle (right figure).





Final project -- Problem 6

Pandigital numbers

A pandigital number is a ten-digit number in which each digit (0 — 9) appears exactly once.

1. Print the smallest five pandigital numbers.
2. Find all pandigital numbers that are divisible by all integers from 1 through 9. If it is too time-consuming, find the smallest two such numbers.
3. Actually, those numbers are multiples of 2520. Explain why, and use this idea to find all. Compare the complexity of the two approaches.
4. Find all pandigital numbers that are the squares of integers.
   If it is too time-consuming, find the smallest two such numbers.
5. Instead of checking all pandigital numbers whether it is a square, consider only integers within an appropriate range, and check whether their squares are pandigital. Use this approach to find all pandigital squares. Comparatively analyze the complexity of the two approaches.