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A Basic Study of Dimensionality

A Quantitative Approach

Scientific Data Acquisition and Processing

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Date of Submission:

October 13, 2024

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Abstract

A brief summary of the experiment.

Keywords

List of relevant keywords

Contents

1 Introduction

In the following experiment our aim is to demonstrate the fractal nature of a very simple physical object: a small tin foil ball.

Fractal objects are objects which are characterised of the self-similarity property, in simpler words, they look the same when observed at different scales. One of the most famous fractal object is the Mandelbrot set, but we can find these objects also in nature, such as in the structure of a Romanesco Caullflower, or from a physical point of view, polymers can be regarded as fractals as well.

Figure 1: An example of cauliflower seen from far away (left) and from up close (right)

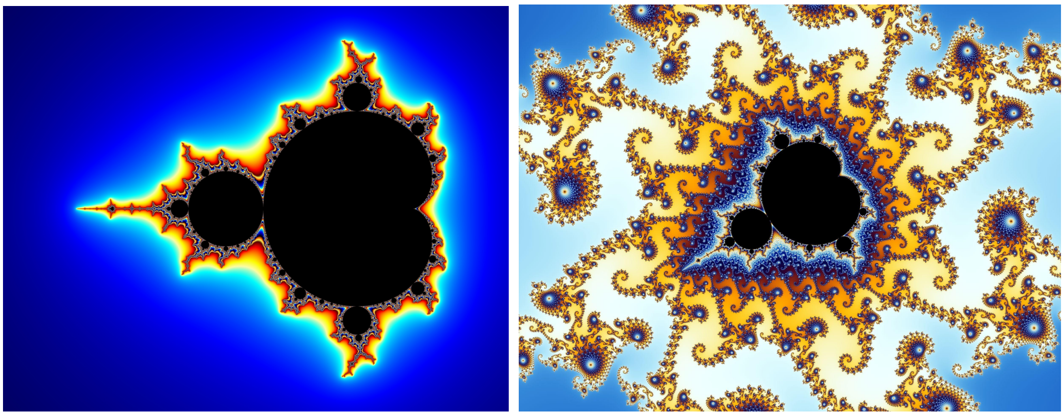

Figure 2: The Mandelbrot set seen from far away (left) and from up close (right)

We can observe the same level of complexity of the images as seen from far away and up close in Fig 1 and Fig 2 above.

From the mathematical point of view, we have to define a fractal from its changes in terms of mass and volume. We start from an object that we know: a square sheet of paper. In this case we will have the mass distributed following the area of the sheet, furthermore the mass grows as the square of the typical lenght of the sheet (the side of the square which we will call r). The formula will be the following

$$M = Cr^2$$

where C is the surface density of the material of the sheet. We can say that the dimension on the sheet of paper is equal to the exponent 2.

We can repat the same reasoning with a metal cube, obtaining ultimately the formula

$$M = Dr^3$$

where D is the volume density of the metal used. It has of course 3 dimensions.

Now let's apply this method to our experiment. Since the physical data which we will obtain will be the mass and the linear dimension of the system (the tin foil ball), the unknown parameters will be the general density k and the dimensionality exponent α in the formula

$$M_{\text{experimental}} = k r_{\text{experimental}}^{\alpha} \tag{1}$$

To sum up, in the following experiment we will see that also a rolled up ball of tin foil can be considered as a fractal.

2 Materials and Methods

2.1 Equipment and Tools

- Precision balance
- Caliber

- Micrometer
- Drawing rule and square
- Scissors
- Aluminum foil

2.2 Experimental Procedure

We begin checking that we have everything at our disposal (Fig 3). Then we start off from the aluminum foil and we cut, using the scissors, a few square sheets of tin foil. We have to be careful in cutting squares as perfect as possible in order to reduce the error in the measurementes, to do so we make use of both the ruler and the square. We cut square of linear dimension of $2mm$, $5mm$, $8mm$, $11mm$, $14mm$, $17mm$, $20mm$, $23mm$, $26mm$ and $29mm$.

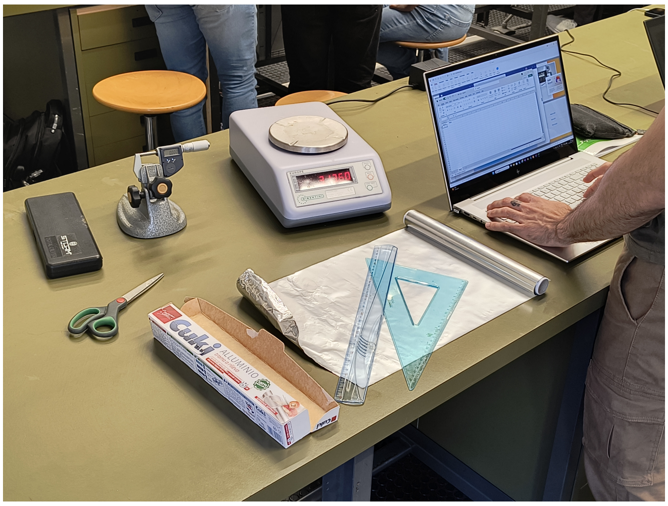

Figure 3: Our laboratory setup

Next, for each square, we measure the mass three times. We also make measurements of the different lenghts of the square as represented in Fig 4. We create an excel table with these measurements.

Now, we roll up every tin foil square into a sphere trying to have each ball at the same density (Fig 5)????????????????????. Since we do this operation by hand, we can only

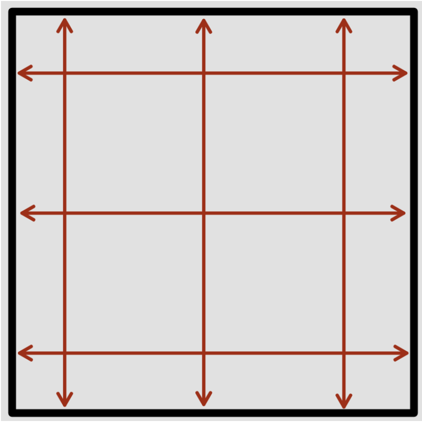

Figure 4: All the direction in which we measured the lenght of the side of the aluminum foil squares

have an idea of its density. This is the step in the procedure which adds up the most indetermination in the experiment.

Figure 5: Some of the balls that me made from the tin foil, the caliber, some squares of tin foil in the background

Once finished, our last measurent will be to collect the information of the linear dimension (the radius) of each ball. We use the caliber or the micrometer (depending on the size of the ball) to measure the diameter of the ball along three different axis. We put this data in an excel spreadsheet.

3 Results

Present all data collected, including graphs, tables, or charts. Explain the trends and observations found during the experiment.

4 Discussion and Analysis

Interpret the results, compare them with expected outcomes, and discuss any deviations or unexpected findings. Address possible sources of error and suggest improvements.

5 Conclusion

Summarize the main findings, confirm or refute the hypothesis, and suggest future research directions or practical applications.

6 Appendix

Include supplementary information such as raw data, calculations, or additional graphs that are too detailed for the main report but are still relevant.