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Evolutionary Computing

Practice 5: Fractals and fractal landscape

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1 Introduction

1.1 Fractals

A definition of a **fractal** is one offered by Mandelbrot in 1986 which is:

A fractal is a shape of parts similar to the whole in some way

A fractal is an object or quantity that displays **self-similarity**, in a somewhat technical sense, on all scales. The object need not exhibit exactly the same structure at all scales, but the same "type" of structures must appear on all scales.

1.1.1 Self-similarity

An object is said to be self-similar if it looks "roughly" the same on any scale. Fractals are a particularly interesting class of self-similar objects. Self-similar objects with parameters N and s are described by a power law such as $N = s^d$ where $d = \frac{ln(N)}{ln(s)}$ is the dimension of the scaling law, known as the **Hausdorff dimension**.

1.2 Example: The Triadic Koch Curve

Figure 1.1 shows the construction of the Triadic curve, it has a dimension of $D = 1.261859$.

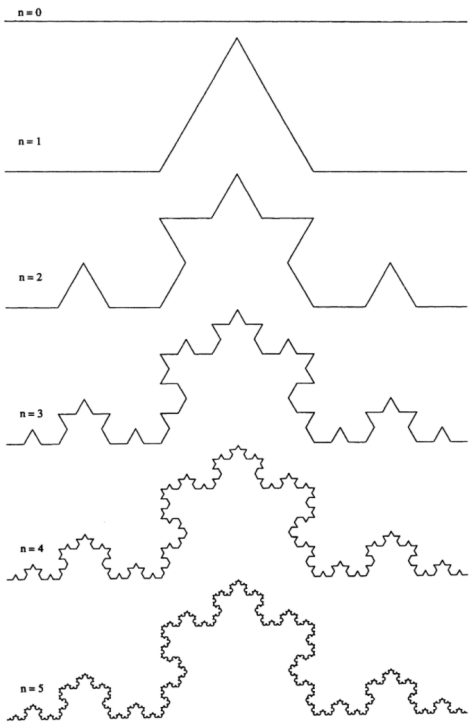

Figure 1.1: Construction of the triadic Koch curve.

The construction of the Koch curve starts with a line segment of unit length $L(1) = 1$. This starting form is called the *initiator* and may be replaced by a polygon such as an equilateral triangle, a square or some other polygon. The construction of the Koch curve proceeds by replacing each segment of the initiator by the *generator* shown as the curve marked $n = 1$ in figure 1.1, and so we obtain the first generation. The next generation is obtained by replacing each line segment by a scaled down version of the generator and so on.

1.3 Dimension of a fractal

The dimension of a fractal can be obtained by counting how many of the initiators are present in the first generation of a scaled version of the initiator.

Using the formula mentioned on the self-similarity section: $D = \frac{log(N)}{log(s)}$, where N is the number of copies of the initiator there are in the first generation of the scaled

up version. For example, for the Triadic Koch curve, the initiator is a straight line, if the line is scaled 3 times its size and produce the first generation, we could see that there are 4 segments identical to the original initiator. So, $N = 4$, $s = 3$ and so $D = \frac{log(4)}{log(3)} = 1.261859$

1.4 Fractals in nature

The main objective of this practice is to use different types of fractals and its visualizations to draw a landscape. There are several possibilities of fractals and many of them can be seen in nature. Fractals can be observed in different parts of nature, such as trees, spiral shells, clouds, leaves, coasts and even galaxies just to mention a few.

Figure 1.2: Example of fractals that can be observed in nature.

Figure 1.2 shows a couple of examples of fractals that an be observed in nature, it can be seen a coast seen from the sky, some clouds, a spiral shell, a spiral galaxy, a fractal tree and a leaf.

2 Material and equipment

Following are the hardware and software used during the realization of this practice. ***Google Colaboratory*** was the tool used for the development of this practice and the next list shows the specifications of the hardware and software provided by Google Colab.

- **Hardware:**
  - **CPU:** Intel(R) Xeon(R) CPU @ 2.30GHz
  - **Memory:** 12GB
  - **Disk:** 108GB
- **Software:**
  - **Platform used:** *Google colaboratory* was used for this practice
  - **Programming language:** Python 3.7.11

3 Development

3.1 Elements of the landscape

For the landscape to elaborate, different fractals are going to be used, some of them will be used to represent things that do not necessarily have this pattern in nature, however, they can characterise pretty well the real life object.

3.1.1 Fractal trees

The first object that is going to be on the landscape is a fractal tree, it starts with a straight line (this is the initiator), then from the end of this line, n more rotated branches grow (this is the generator). The parameters such as the rotation angle, the length of the initial branch, the thickness of the branches, the number of branches and the scale of the new branches can be changed to generate several effects. Figure 3.1 shows a simple example of a fractal tree that generates 3 branches every time.

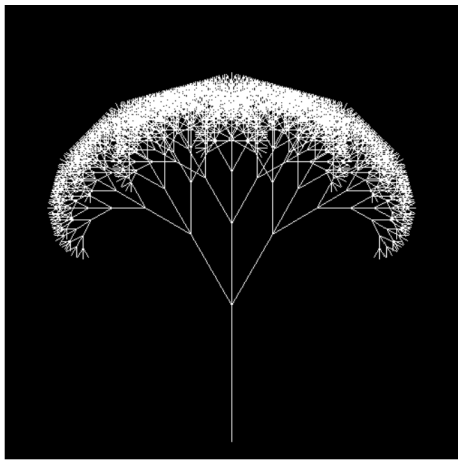

Figure 3.1: Example of a fractal tree.

Even though figure 3.1 looks a lot like a tree, it does not look like a natural tree, since the angles, and proportions are perfectly symmetrical, for that reason, it was decided to add randomness to the generation, so that the tree resembles more to a natural one, also, colors and a thickness that decreases with each generation as well as leaves that were added at the end of the final branches to make it even more realistic. the final result can be observed in the final picture of the landscape.

3.1.2 Fractal clouds

Another object to put in the landscape are clouds, to generate clouds, the initiator is a simple circle, and the generator is to generate three points rotated by some degrees

around the initial point and draw three circles, this will give the effect of a cloud. Figure 3.2 shows an example of fractal clouds, it generates three more circles every time.

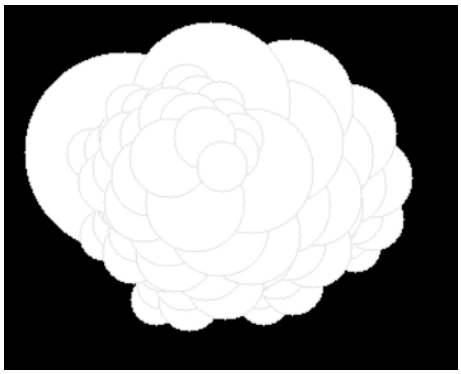

Figure 3.2: Example of a fractal cloud.

3.1.3 Fractal sun

Sun is usually represented as a point with many light rays emanating from it. So, to represent this object in the landscape, the nautilus shell fractal will be used. The initiator for this fractal is a straight line, the generator is a rotation and a down scaling of the initial line. Figure 3.3 shows an example of this kind of fractal, it generates several lines around the same point rotated by 30 degrees.

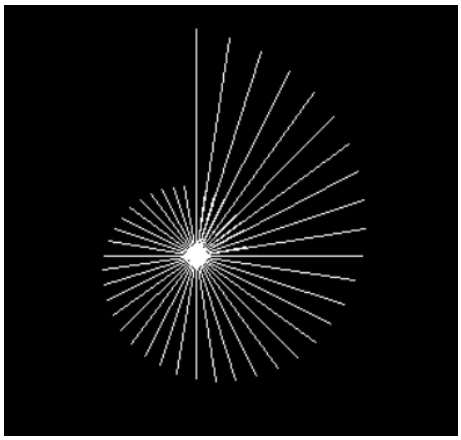

Figure 3.3: Example of a fractal nautilus shell.

To achieve the effect of a sun, the parameters were changed, so, the rotation is going to be greater and color was added to make it more realistic, while the rest of the parameters remained the same.

3.1.4 Fractal mountains

It could be observed that one of the fractals generated a circle, with non smooth borders, so, it was decided to use this pattern in this kind of fractal to represent mountains in the background, so, only a segment of the circle is going to be used for this purpose. The initiator for this fractal is a line, and the generator is to create another rotated line at the end of the original but with the same scale. Figure 3.4 shows an example of this kind of fractal.

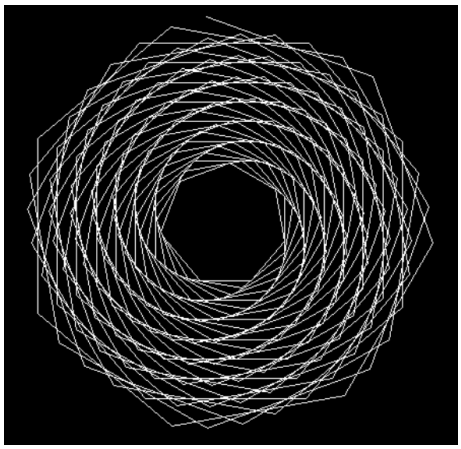

Figure 3.4: Example of a circular fractal.

To represent the mountains, the thickness of the lines was increased and some color was added, also, the position of the generation was changed, in order to get only a segment of the circle.

3.2 Final landscape

The elements described above were unified into a single image to generate a landscape. Some randomness was added to the generation of the elements to give a more realistic effect. The script to generate the landscape can be found by clicking **here**. And so, without further ado, the figure 3.5 shows the landscape generated using the elements described earlier.

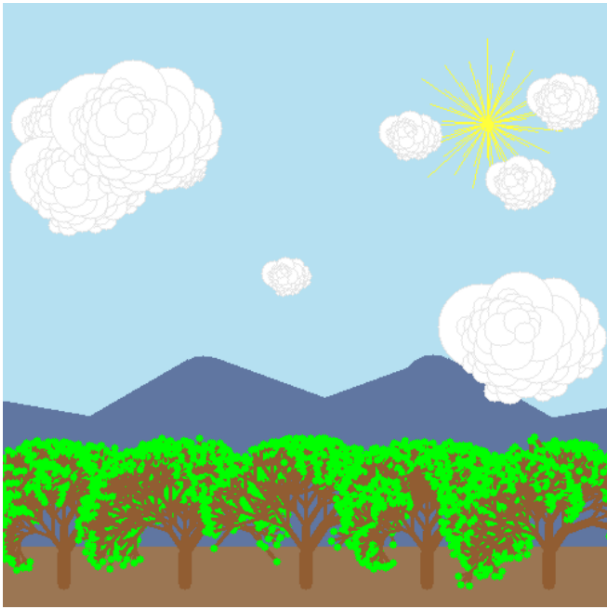

Figure 3.5: First generation of the landscape.

Figure 3.6 shows another generation of the landscape, it can be seen, that some of the elements are positioned differently and the generations of the fractals changes.

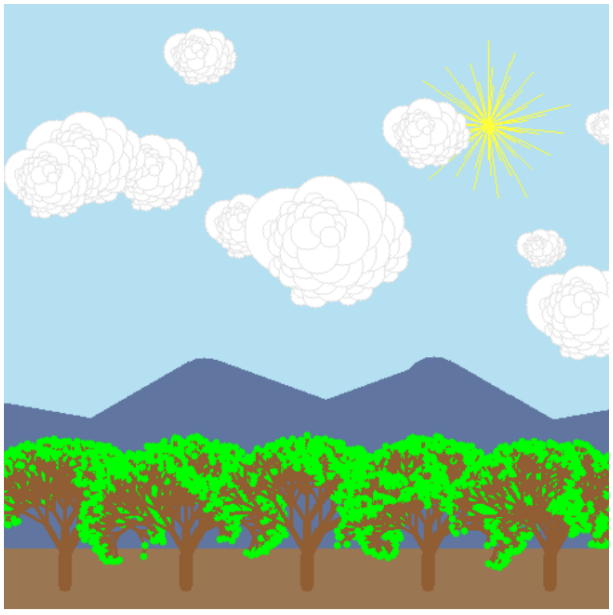

Figure 3.6: Second generation of the landscape.

4 Conclusions

The development of this practice resulted in a better understanding of fractals, doing an investigation of the definition of fractals helped to realize that they are a quite important research topic, it was interesting to see the logic behind them and how the fractals can be observed in nature.

It was concluded that fractals are present everywhere in the nature, even if some things don not look a lot like fractals. It was also concluded that using fractals and adding a couple of factors like the variation of parameters and adding randomness can generate fractals that highly resemble to the real world nature.

While trying to make trees more realistic, a point was reached where the branches seemed quite well, however, some of the branches were growing too much, so it was added another parameter to limitate the radius of the trees and make them look more as a ball and eliminate the overgrown branches.

5 Bibliography

- **Feder Jens (1989). Fractals. Oslo Norway, University of Oslo. Springer Science.**
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- **Rosas Jorge. (2021). Fractales. ESCOM - IPN. Class Lecture.**