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Le hasard à l'œuvre (the random in the artwork)

Paper and Live Performance

Topic: Art, Mathematics and A.I.

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Abstract:
Although art abstract paintings are fairly chaotic, certain patterns can be extracted from some artworks. The idea is to develop software that tries to imitate the development of a painting using equations to model it. Then, using this principle try to create an experienced based software using artificial intelligence (A.I.) to develop images which depend on what the user considers as beautiful. To explain it in detail; we will use as an example the Fig. 1 (left) from artist Gildas Bourdet[1]

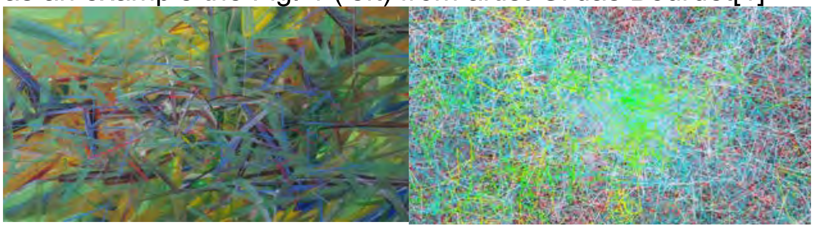

Figure1. Painting made by [1] (left) reconstruction using software (right).

In this paiting although created using random strokes, we can see that there is a center point from which all strokes originate. This was modeled by an algorithm which creates a set of strokes each millisecond based on the equation of the spiral by introducing random variables in the equation. If instead of using random variables in the code we used fixed values for length, angle and color we get the results as in Fig 3 (left).This is the base of the algorithm for A.I.. Instead of using random parameters for the spiral equation in time, we used the Fast Fourier Transform (FFT) [2] to obtain the coefficients by analyzing different signals using music (Fig. 2),or using the heart-beat [3] (Fig. 3) (right).

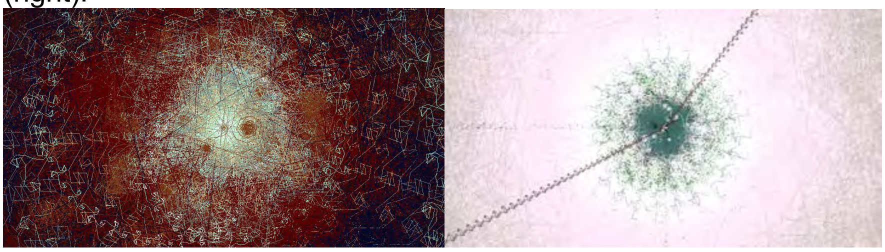

Figure 2. Images created using FFT analysis.

The A.I. is included in the fact the user can choose an image, and the software will try to build similar results. The software works dynamically; this means it generates a different image each ms. There are no 2 equal images.

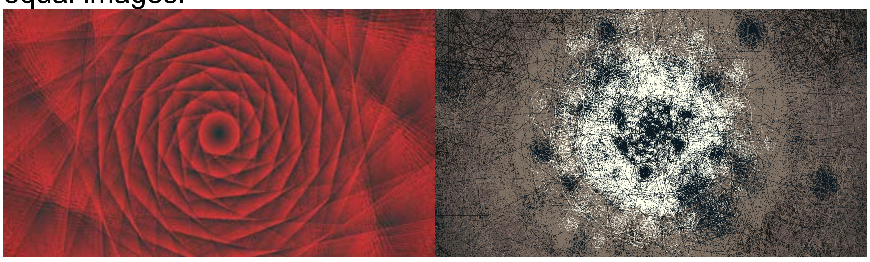

Figure. 3. Image created using the spiral equation with fixed parameters (left).Image created using the heart-beat as base (right).

References:
[1] Gildas Bourde "*Peintures et Dessins*", CASTA DIVA, Paris, 2012.
[2] Inside The FFT Black Box. Serial And Parallel Fast Fourier Transform Algorithms, March 2001CRC Press.
[3] Software for inverse voltage calculations in the heart's surface Ainseba, B. ; Bendahmane, M. ; Lopez, A. Electrical, (CONIELECOMP), 2012 22nd International Conference on Publication Year: 2012 , Page(s): 34 - 39

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Le hasard à l'œuvre (the random in the artwork)

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Abstract:
Although art abstract paintings are fairly chaotic, certain patterns can be extracted from some artworks. The idea is to develop software that tries to imitate the development of a painting using equations to model it. Then, using this principle try to create an experienced based software using artificial intelligence (A.I.) to develop images which depend on what the user considers as beautiful. To explain it in detail; we will use as an example a painting from artist Gildas Bourdet.

In the paiting although created using random brushstrokes, we can see that there is a center point from which all strokes originate. This was modeled by an algorithm which creates a set of brushstrokes each milisecond based on the equation of the spiral by introducing random variables in the equation. If instead of using random variables in the code we used fixed values for length, angle and color we get the similar results. This the base of the algorithm for A.I.. Instead of using random parameters for the spiral equation in time, we used the Fast Fourier Transform (FFT) to obtain the coefficientes by analyzing different signals using music or using the heart-beat.

The A.I. is included in the fact the user can choose an image, and the software will try to build similar results. The software works dynamically; this means it generates a different image each ms. There are no 2 equal images. This leads to an important question: how much random does an artwork really has?

1. Introduction

The mission of art is not to copy nature but to express it [4]. The title Le hasard à l'œuvre (the random in the artwork) comes from an art exposition in the Galerie MLS at Bordeaux. This work started from the analysis of the art work from painter Gildas Bourdet[1], which is shown in the Figure 1.

Figure 1 "Untitled" reproduced here with express permission from the author.

Although the artist started making this picture with no calculated pattern, a similar image can be generated using an algorithm. We will explain this using the painting as a basis to our algorithm. Let's consider the artist used a starting point (consciously or unconsciously), and from there he started making the brushstrokes until he fill the image, the starting point in question is marked in Figure 2.

Figure 2 Supposed starting point for the brushstrokes.

Using an algorithm we can create a similar image or at least with the same principle (Figure 3). The base to this image is the model of the spiral in time.

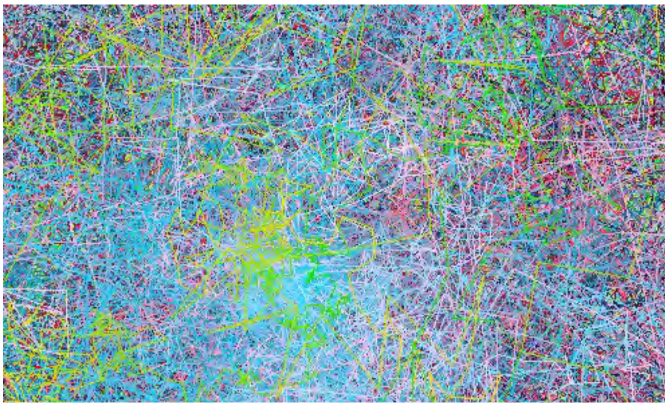

Figure 3 Created Image trying to imitate the painting's procedure.

To develop a software to create images similar to the paintings, we used turtle graphics. Turtle graphics is a way to draw curves in the plane [5]. The idea of turtle graphics comes from the concept of a turtle moving in one direction and its tail leaving a trace. It consists of four basic instructions:

- Move forward a fixed length *l*, and draw a line from the last position to the new one.
- Move forward a fixed length *l*, and move from the last position to the new one (do not draw a line).
- Turn left by a fixed angle α.
- Turn right by a fixed angle α.

If we choose randomly the length *l*, and the angle α we will create a sequence as in Figure 4.This is known as random walk.

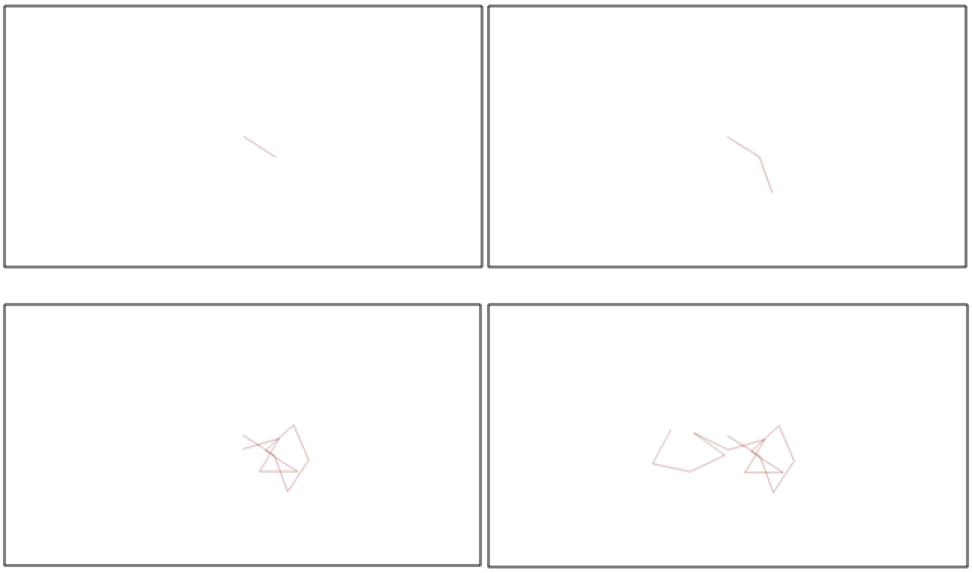

Figure 4 Procedure to create sequence using Turtle Graphics.

Repeating this procedure several times, until we fill the canvas we can construct an image as in Figure 3.

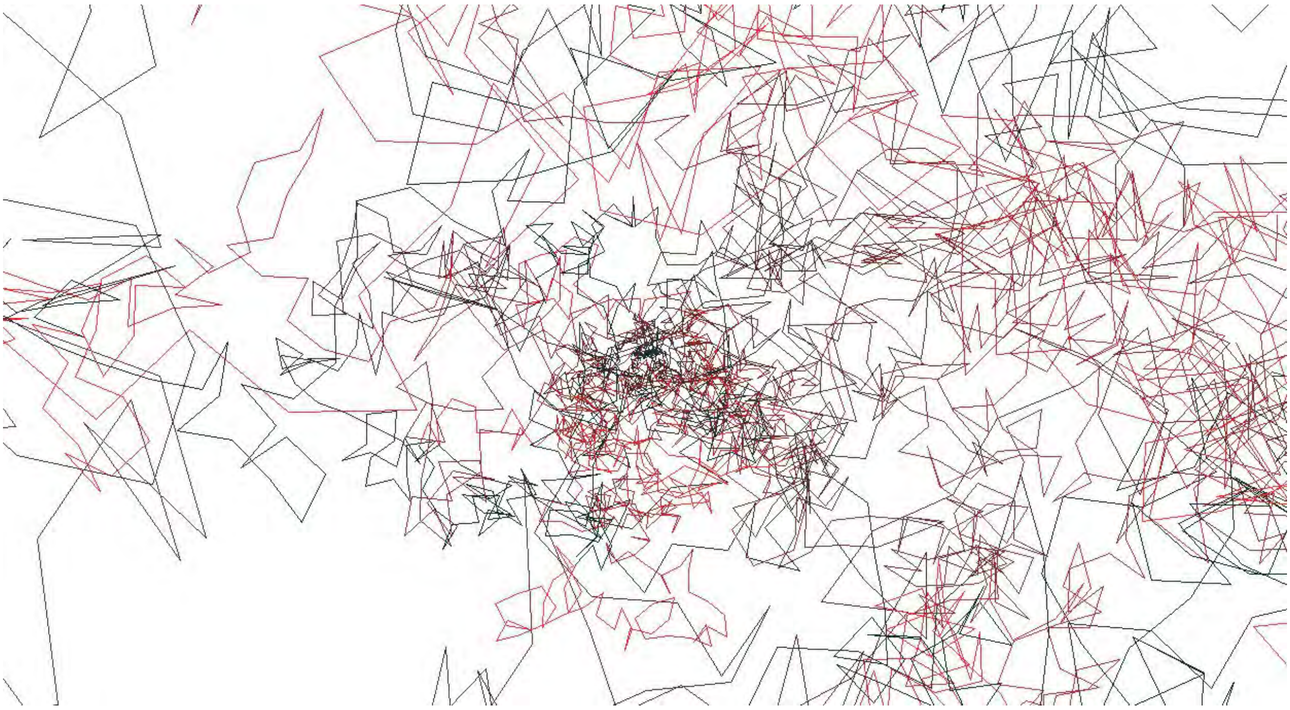

Figure 5 Procedure to create a random image.

This seems as an arbitrary set of lines, but actually this is the model of the spiral. If we fix the angle α, and we draw a series of lines using the turtle graphics we can create a series of orderly images. We will declare an interruption each amount of milliseconds to draw in the canvas, and using the following function for N lines:

```
for (M = 0; M < N; M++)
{
        Turtle forward(M);
        Turtle turn left(α);
}
```

Using this procedure we can create an ordered spiral, as in the following images (the chosen colors are a function of time):

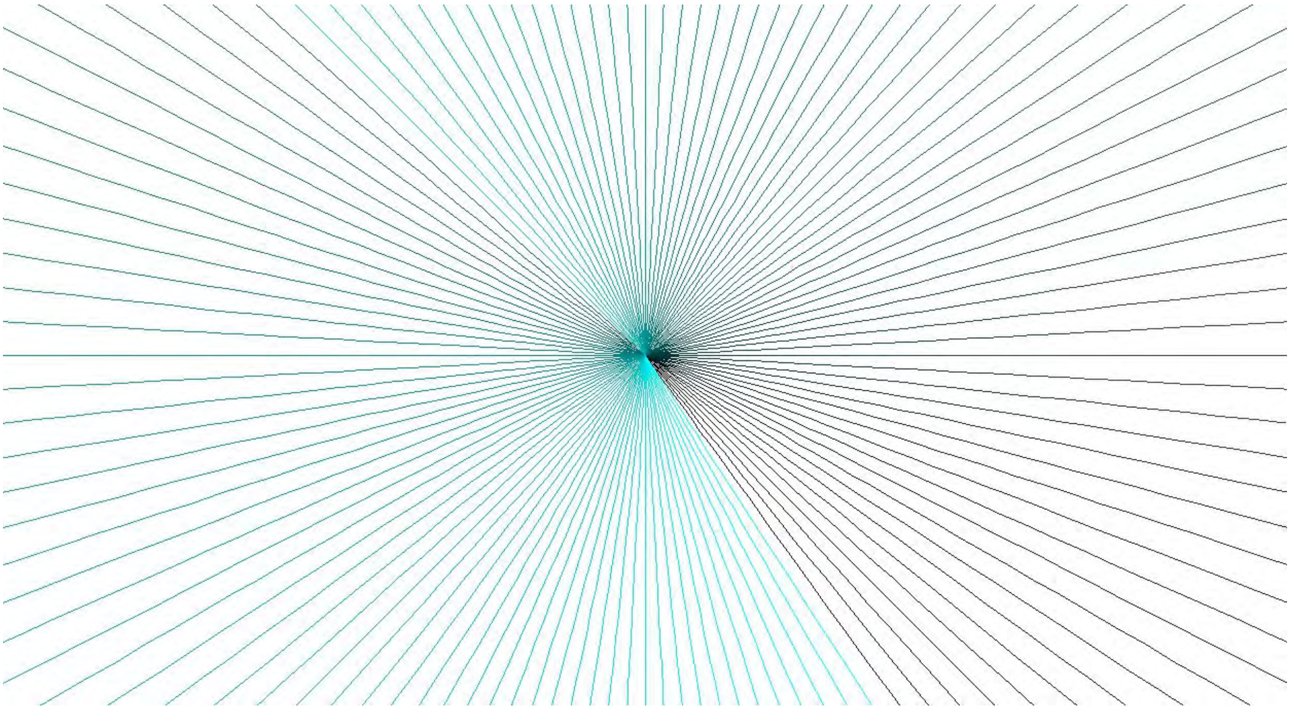

Figure 6 Generated image using α=0.

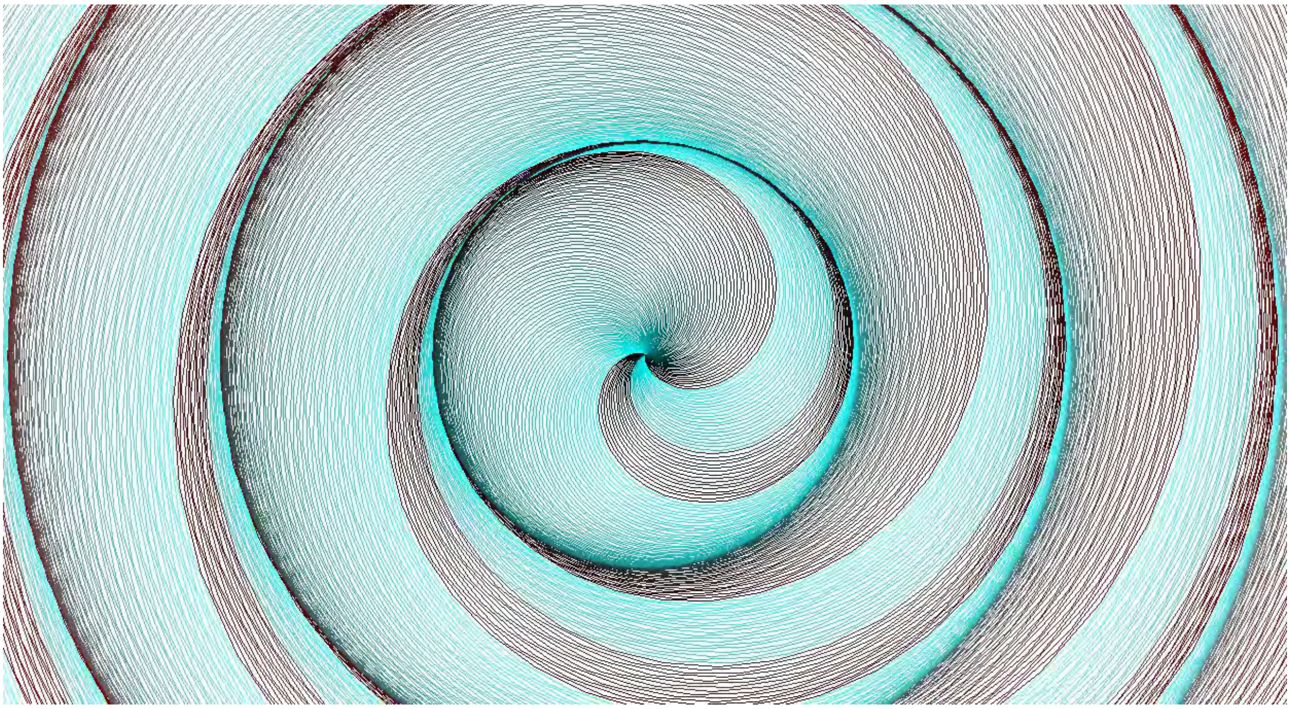

Figure 7 Generated image using α=10.

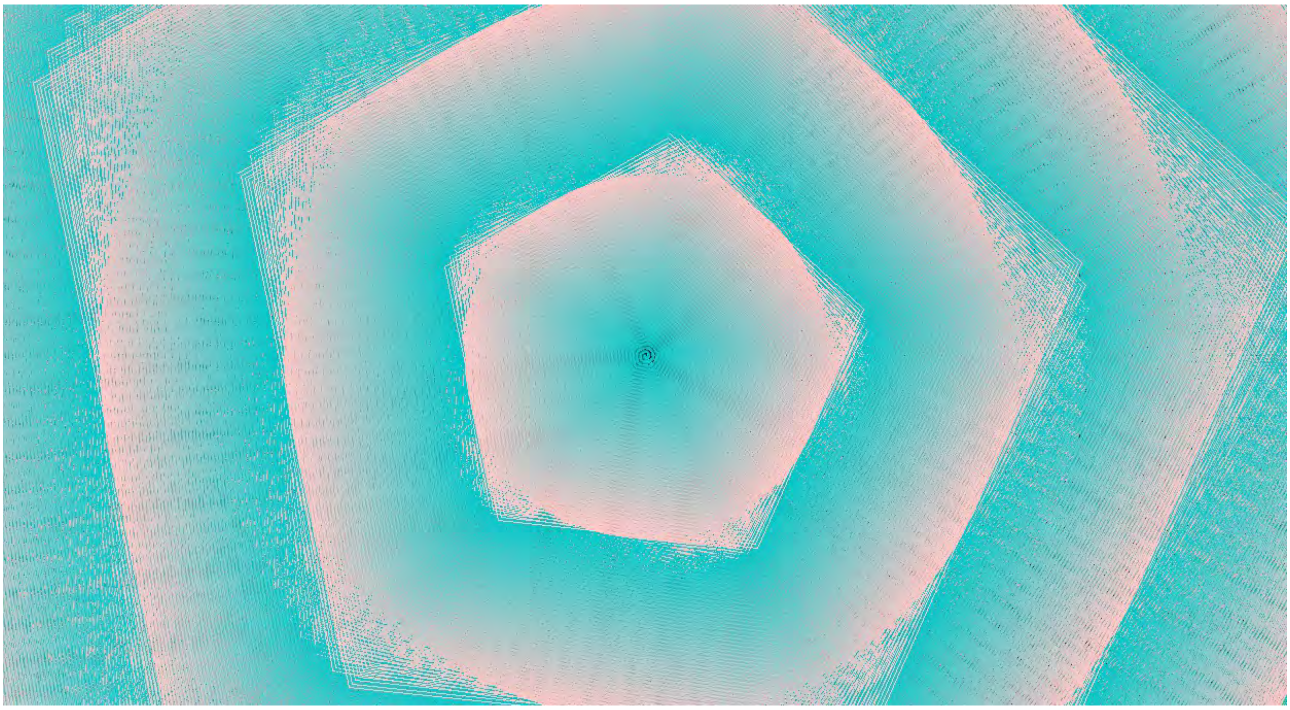

Figure 8 Figure 7 Generated image using α=72.

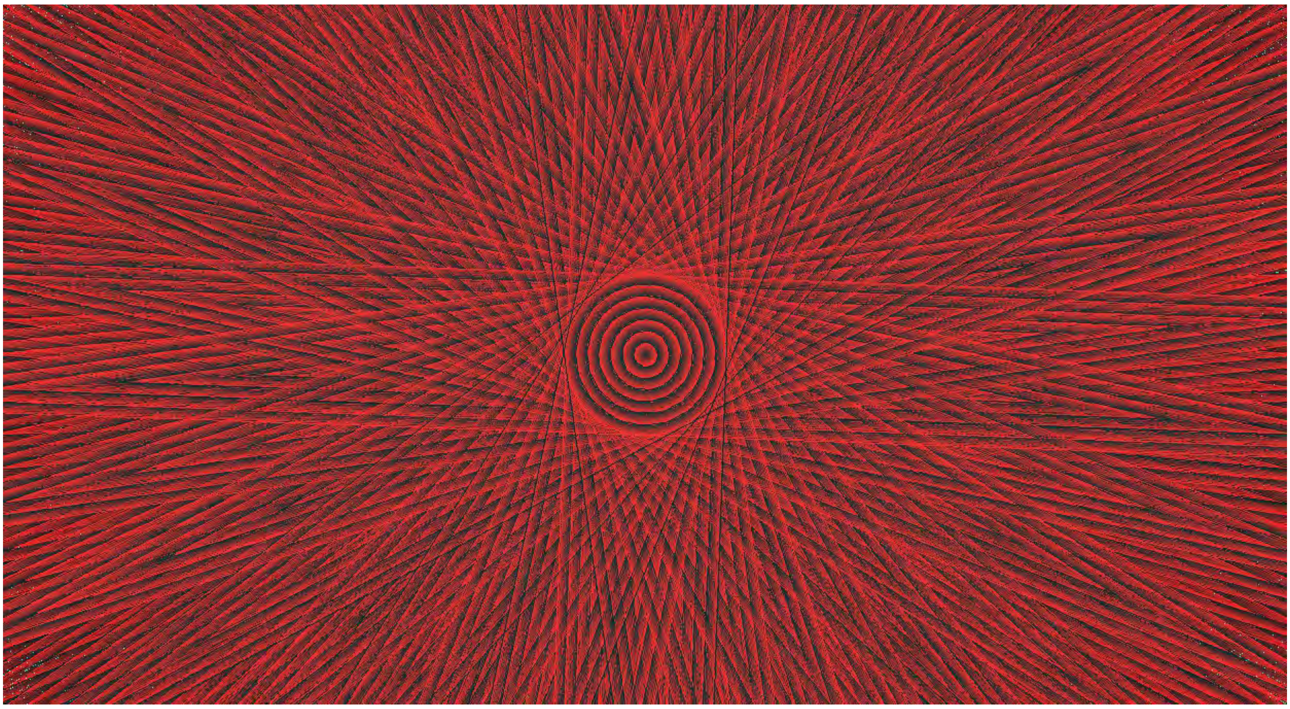

Figure 9 Generated image using α=170.

These images can be seen as ordered spirals, this was the base to create our artwork. . Spirals appear in a lot of models in nature , for example in the model of electrical activity of the heart an impulse is generated at a point and it propagates through the plane creating a spiral wave depending of the conductivites in the heart, similar examples can be found in other models of nature.

As an example the simulation of the electrical activity of the heart in 2D and 3D using the bidomain model [6]:

Figure 10 Simulation of the electrical activity of the heart in 2D from [8].

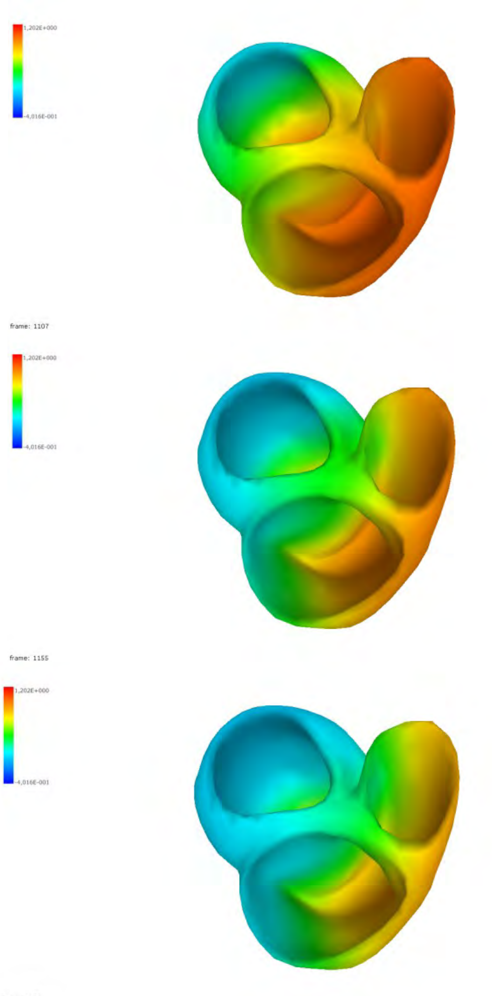

Figure 11 Propagation of the electrical spiral wave in the heart in 3D in the ventricles [3].

2. A step forward

Taking the spiral model in time as explained in the above section we used it as a base to create a new set of images. Instead of just creating random walk with random colors; we controlled the parameters of the created images choosing the different values from a set of coefficients. The pseudo code for the algorithm is the following:

```
for (i = 0 to i < FFT length)
{
        values_n[i] -= (values_(n-1)[i]);
}

for (M = 0; M < N; M++)
{
        Color =function(values_n)
        Turtle forward(M and function(values_n));
        Turtle turn left(function(values_n));
}
```

As we can see the colors, length (*l*) and angle α will be chosen by the a set of values (*$values_n$*) this values will be given by the decomposition of signals using the Fast Fourier Transform [2]. The resulting images one may consider that in every case they are the same for the same signal, but it is not the case. The algorithm depends of the processor interruptions, therefore it creates randomness implicitly due to the timer interruption in the programming language is inexact, although if necessary random variables can be introduced into the system explicitly. Using music as a base for the system we can create theoretically infinite sets of images, some examples:

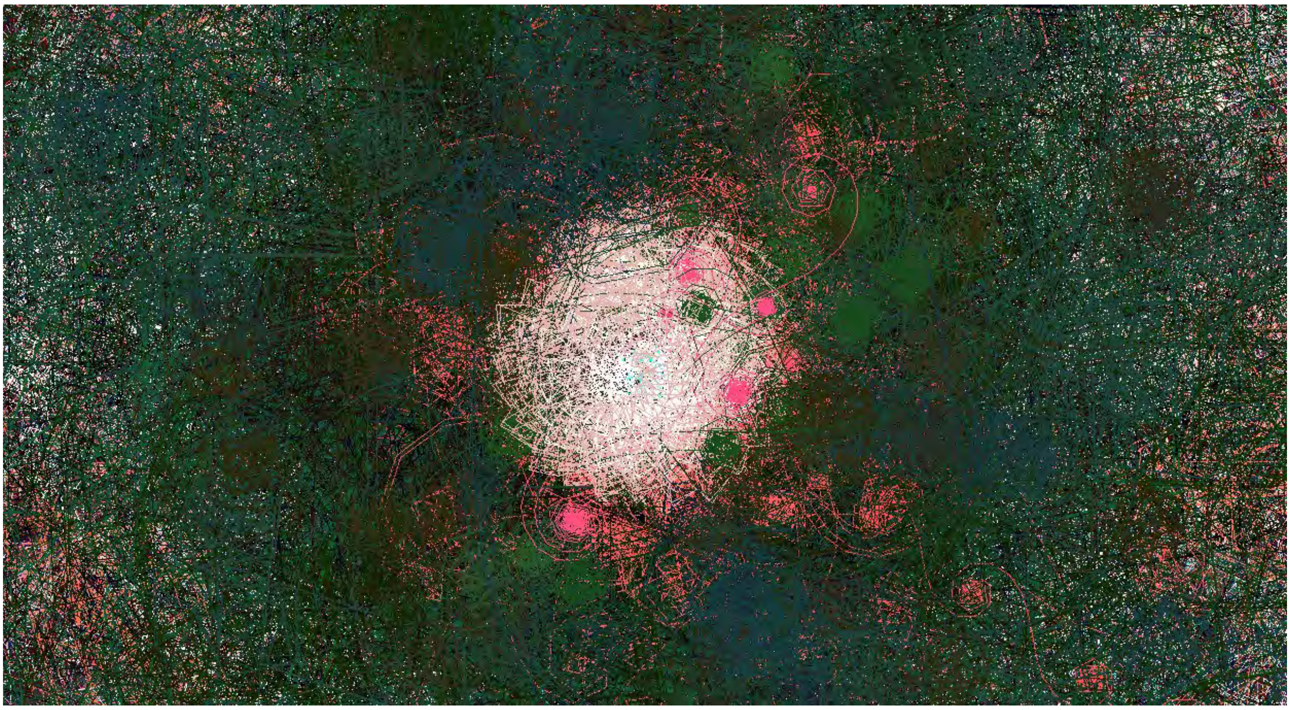

Figure 12 Untitled.

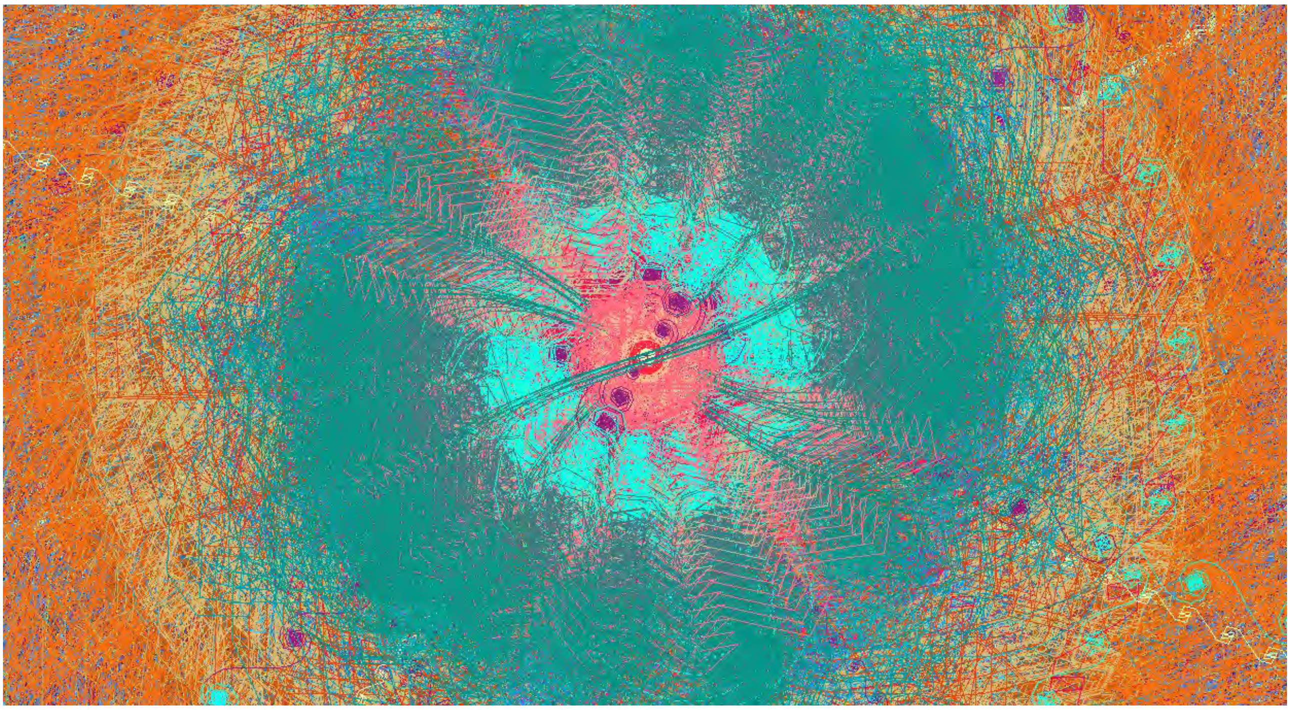

Figure 13 Untitled.

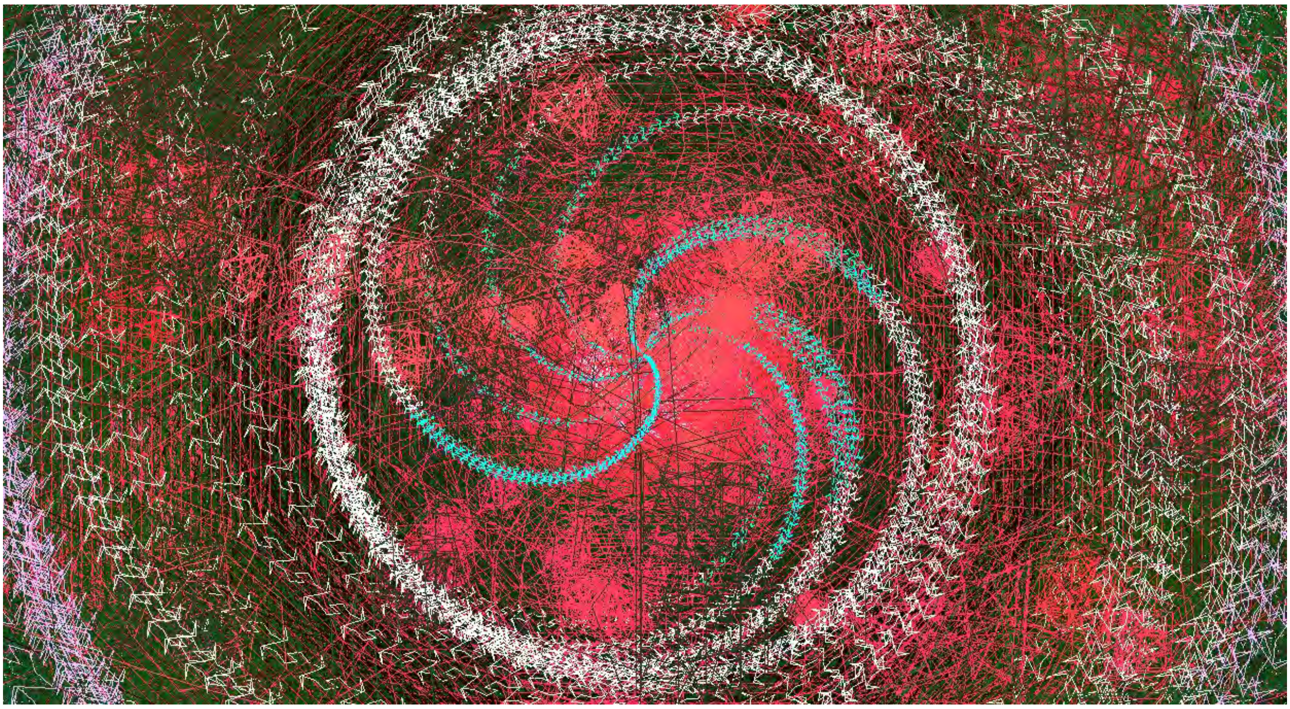

Figure 14 Untitled.

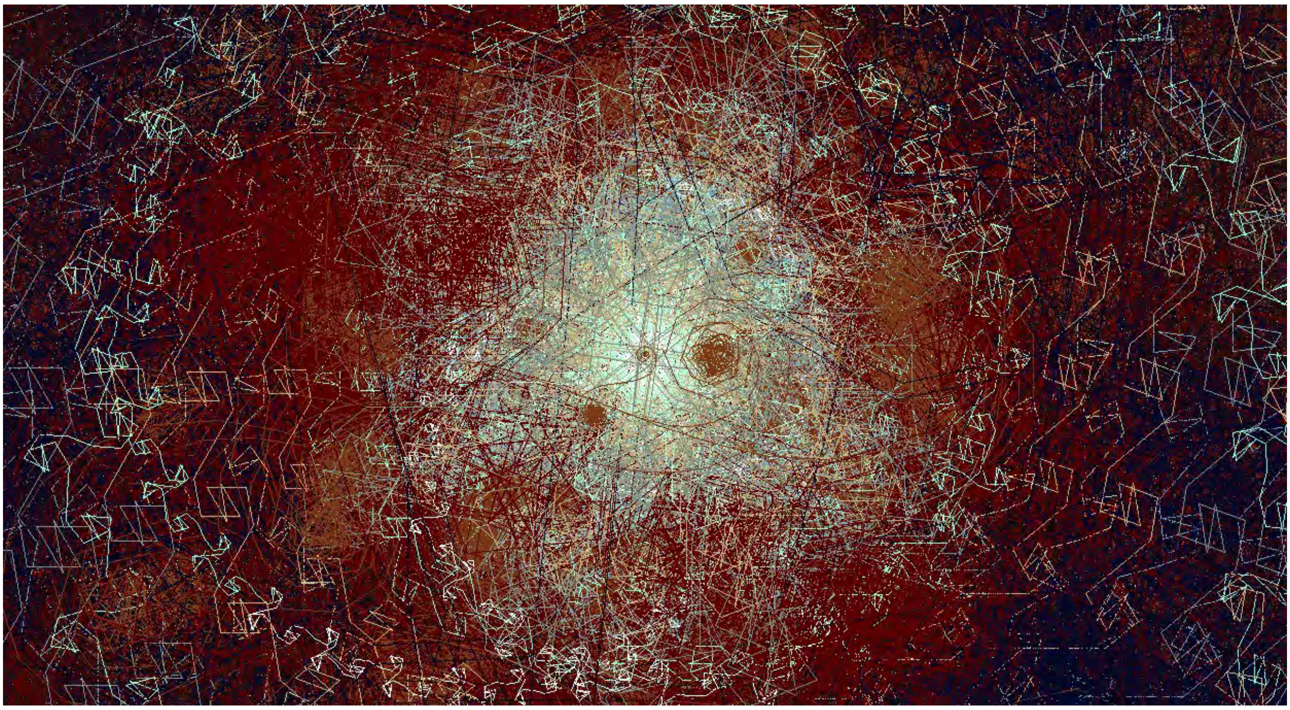

Figure 15 Untitled.

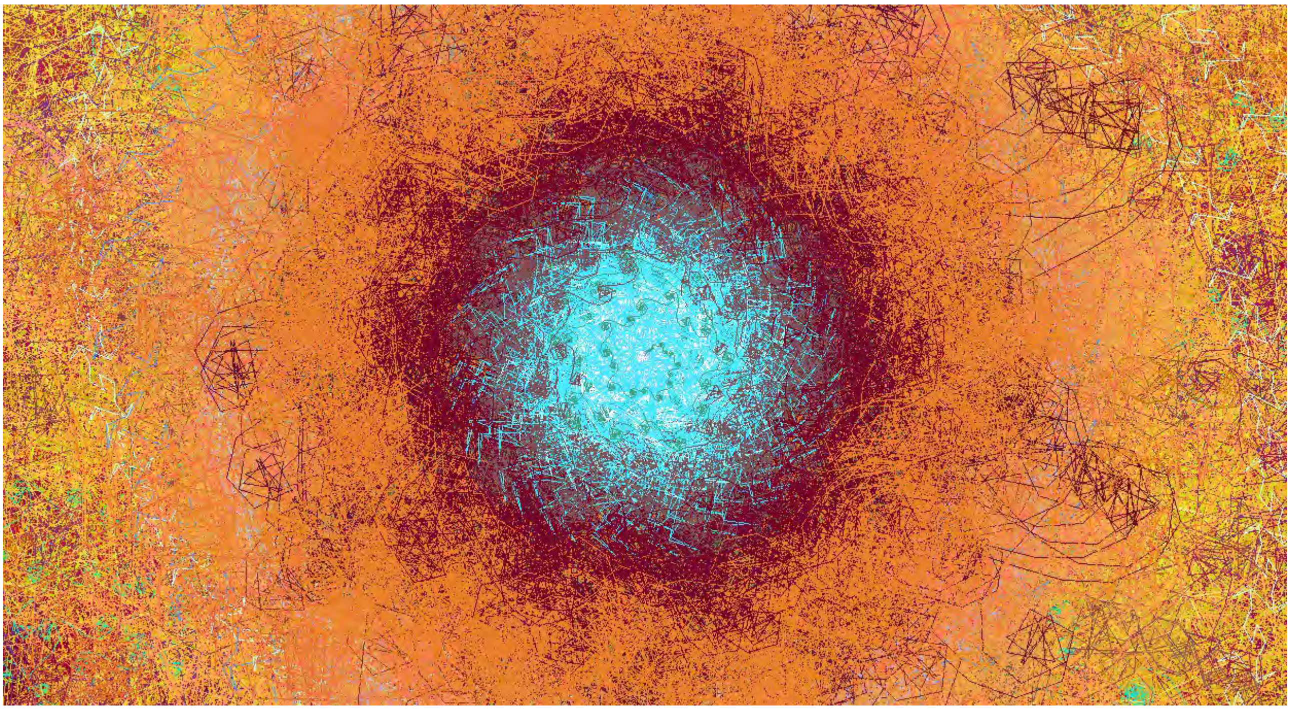

Figure 16 Untitled.

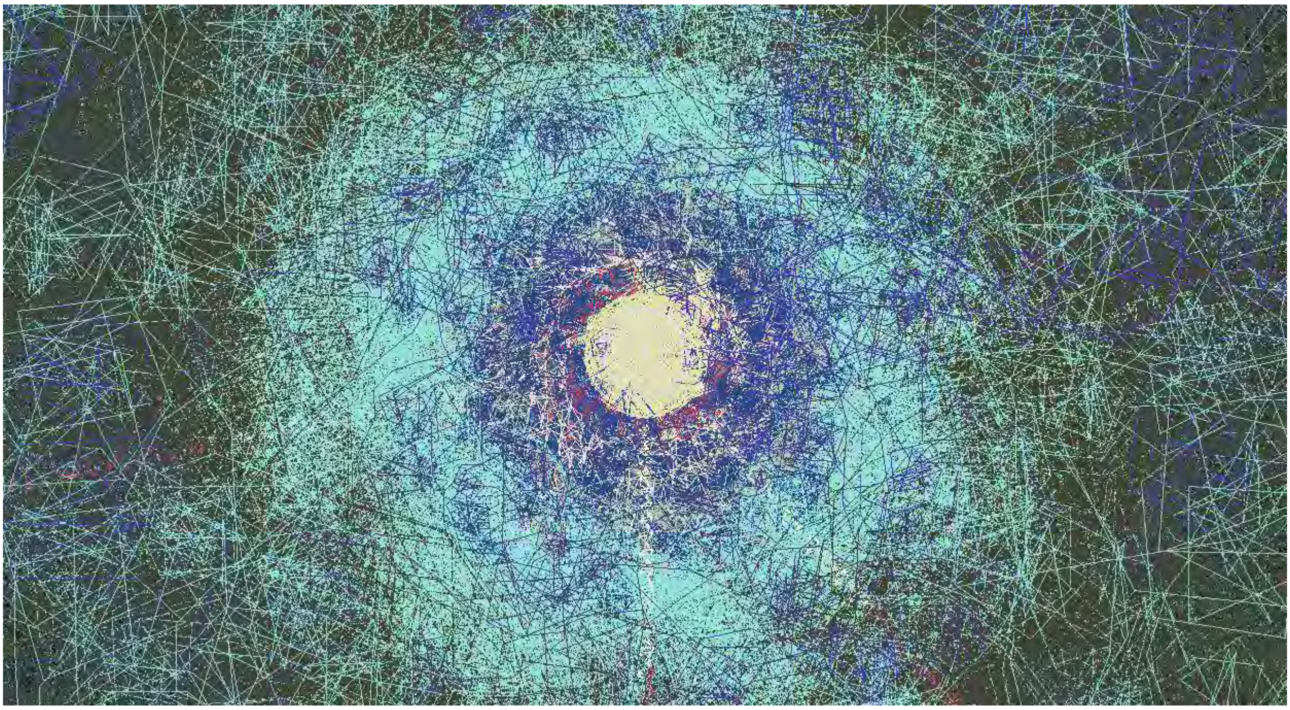

Figure 17 Untitled.

3. Coding the Heart

The images of the last section were created using music for the signal that will be traduced into images. The following set of images was created using the heart beat as the base of the signal. This is a project in development.

To capture the bioelectric signal coming from the heart, it is necessary a circuit to capture the signal in a bipolar lead configuration. The bipolar lead is to put two electrodes over the chest, and an extra electrode as a reference.The electrodes are made of AgCl and a gel to avoid mechanical noise.

In Figure 18 there is the used front-end to acquire the ECG signals. The circuit amplifies 500x the bioelectric signal using a differential amplifier. The circuit has 4 filtering stages, and an adding level stage to have the voltages in the range of the microcontroller (0-5 V). The first one is an active shielding. The second one is a resistive-capacitive low-pass filter with a 97 Hz cut frequency. The next stage is a first order high-pass filter with a cut frequency of 5 Hz. The last stage is a noth sallem-key filter with a center frequency of 60 Hz. This filter can be easily modify for a center frequency of 50 Hz (europe).

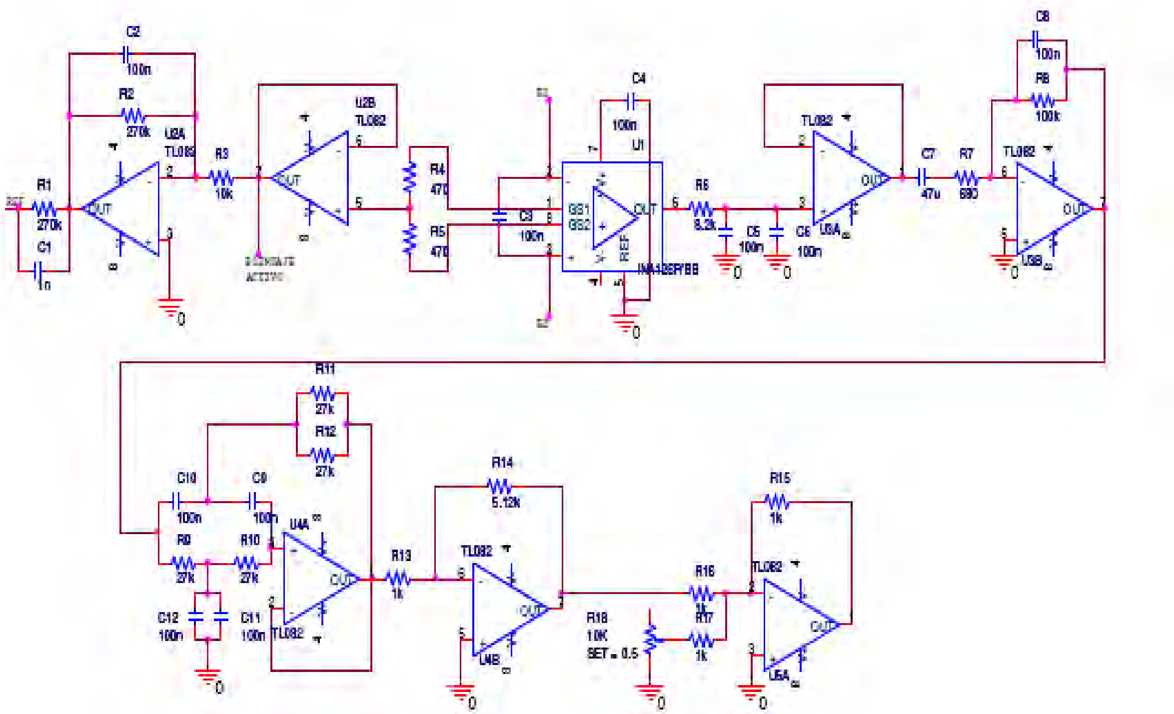

Figure 18 **Electronic acquisition hardware.**

For example in Figure 19 we can see the measures of the heart, and in Figure 20 the FFT transform [2].

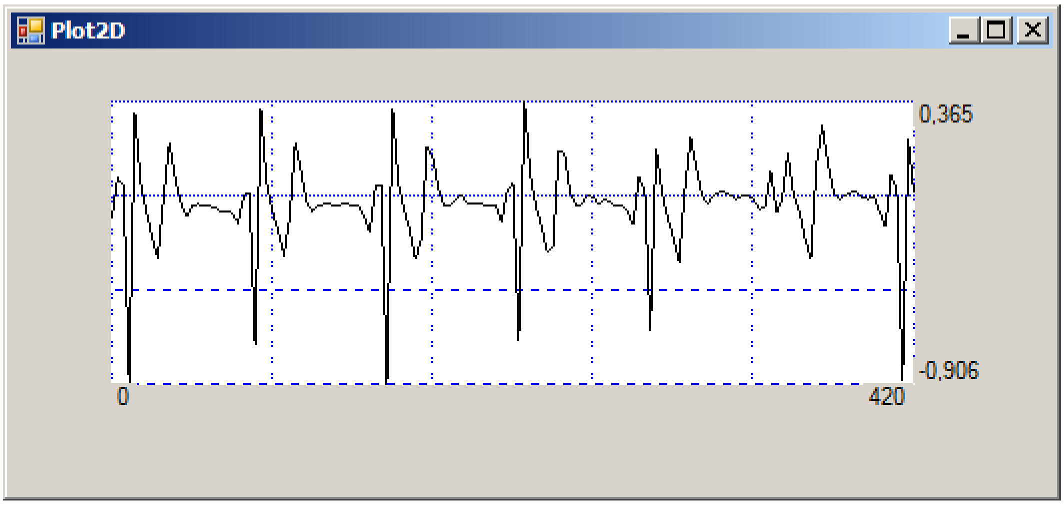

Figure 19 Heart Measures.

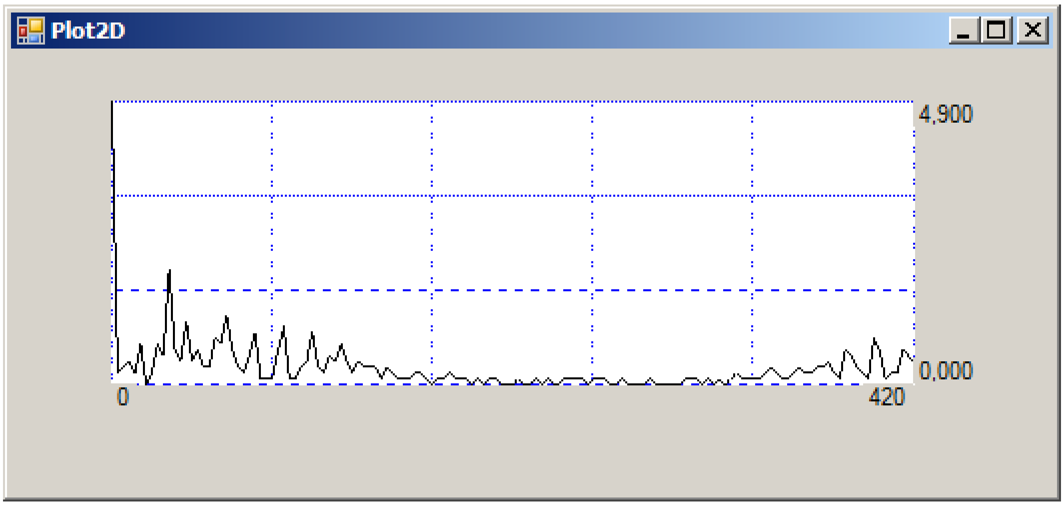

Figure 20 FFT Transform.

From my heart measures we create a set of images using the FFT coefficients:

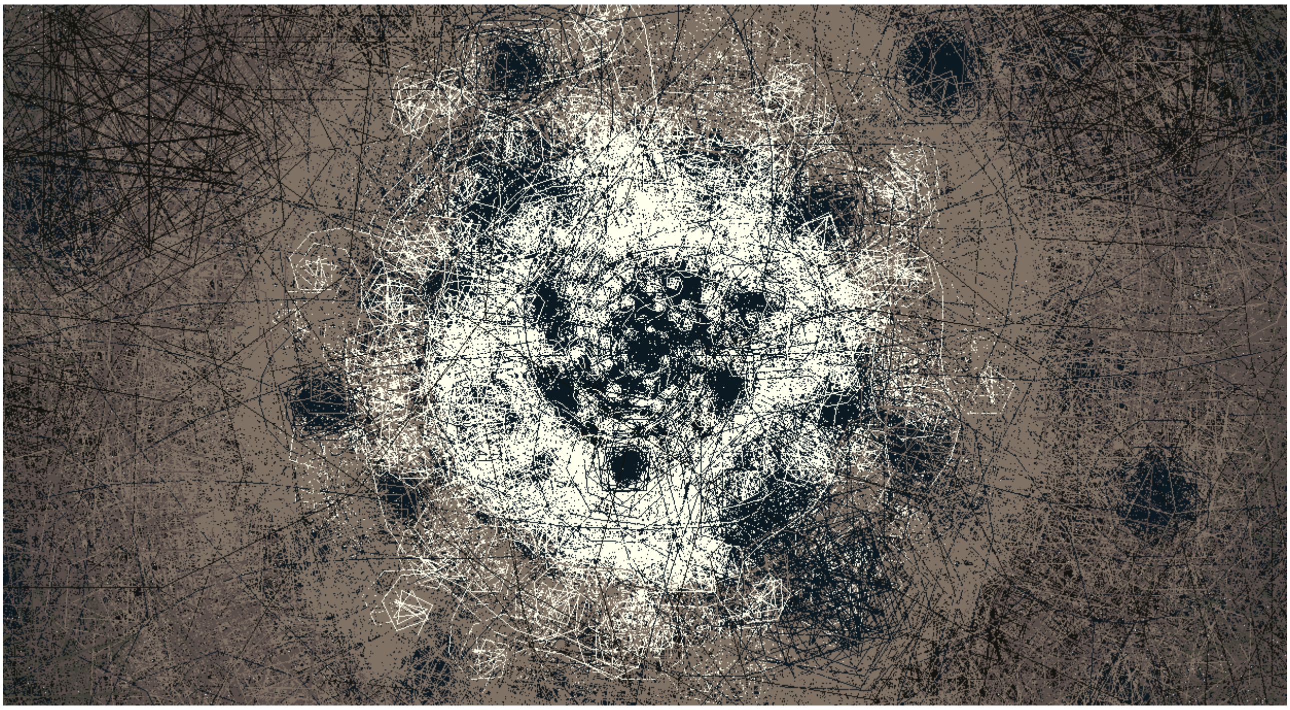

Figure 21 Love Declaration I.

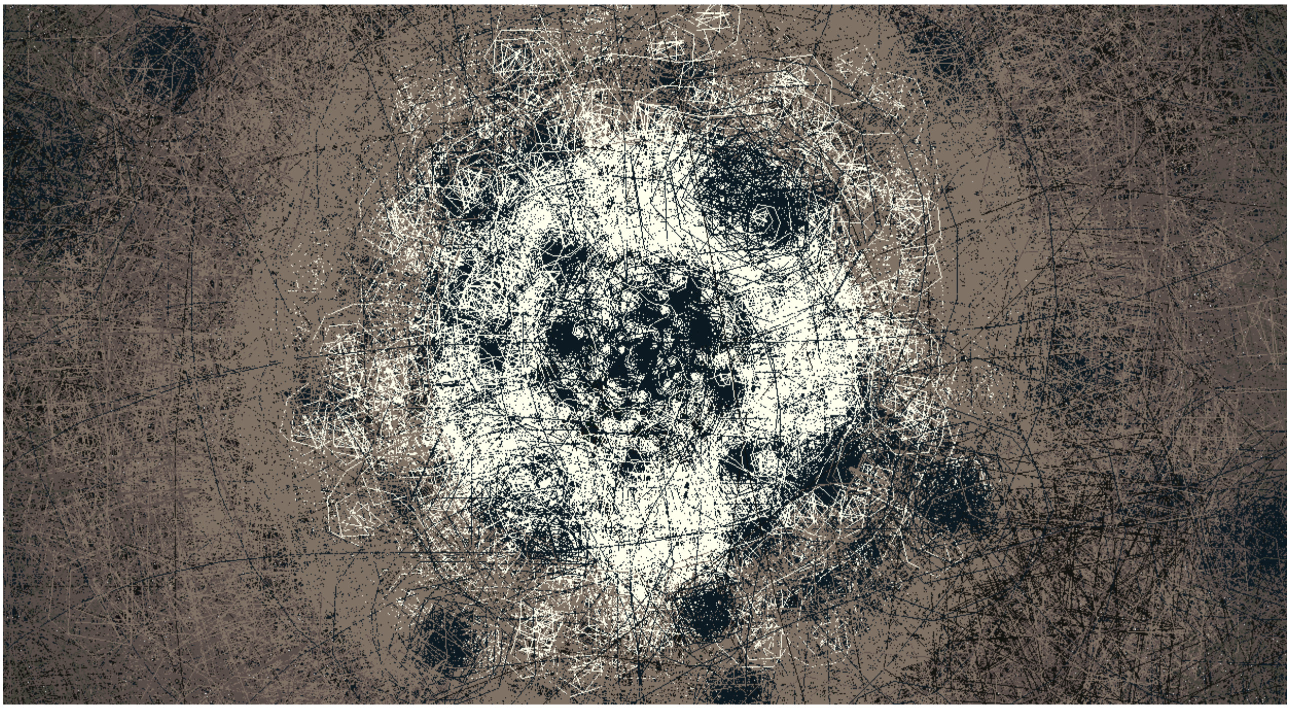

Figure 22 Love Declaration II.

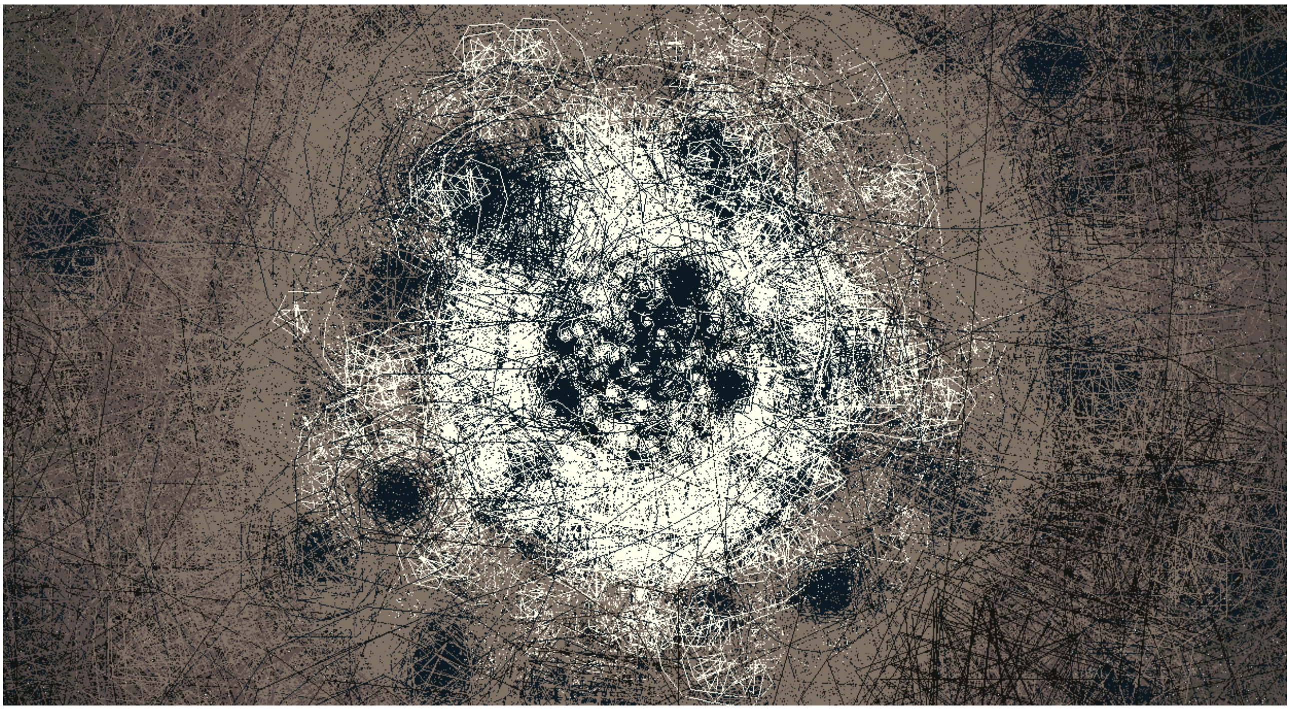

Figure 23 Love Declaration III.

4. The Next Step

There are two paths to continue developing this project. The first one is to bring the images to the real world using classical techniques. For example from Figure 24 we create a painting using acrylic on canvas (Figure 25). The same case for Figures 26 and 27.

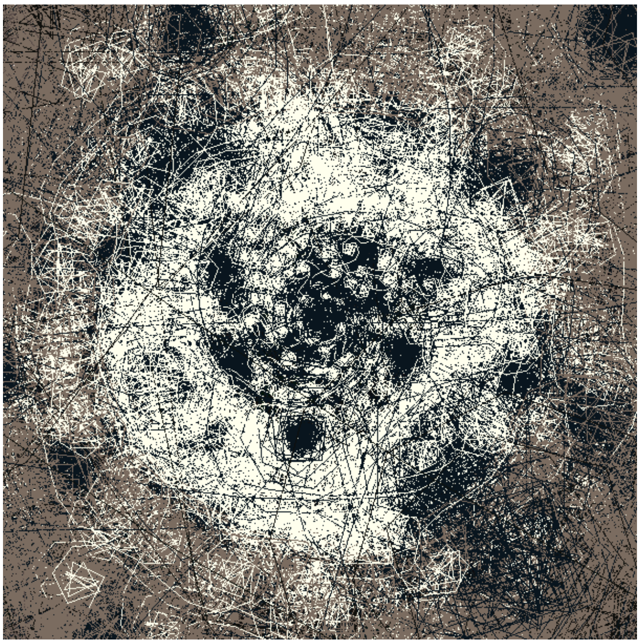

Figure 24 Love Declaration (detail).

Figure 25 Love Declaration (acrylic over canvas).

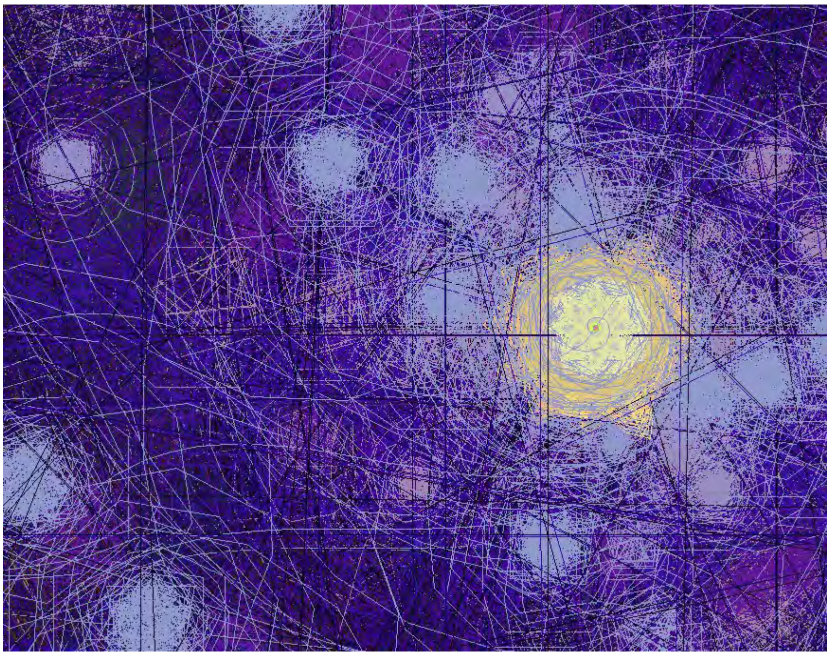

Figure 26 Galaxia.

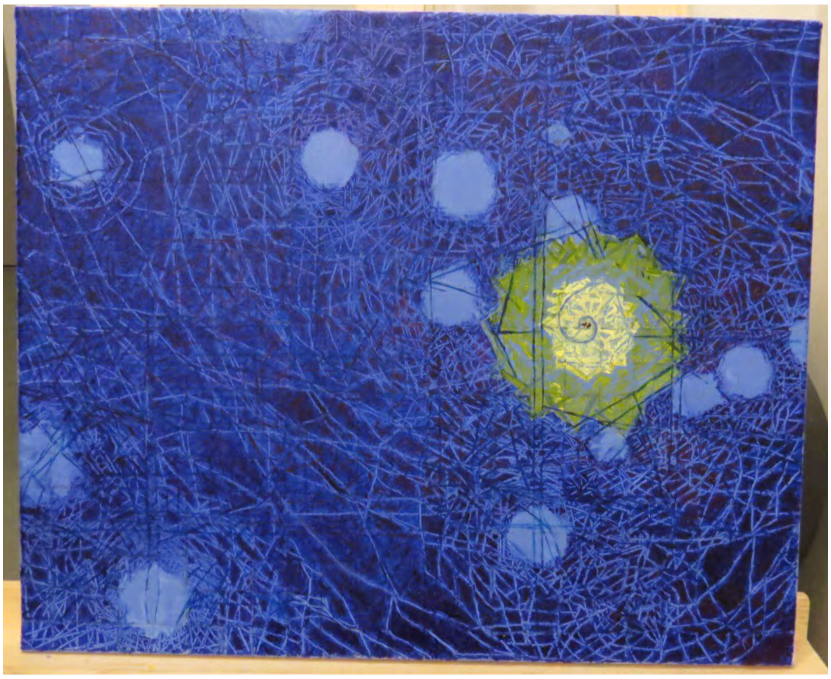

Figure 27 Galaxia (acrylic on canvas).

The second path is to develop the software using artificial intelligence (AI). Using particle swarm optimization (PSO), we created a software that while using music as a base for the images; when the user loves an image; then it saves the coefficients and starts generating similar images.

PSO is a population-based evolutionary algorithm. based on the social behaviour of birds flocking and fish schooling, it was firstly introduced by Kennedy and Eberhart [7]. The population denominated as swarm uses a number of particles (candidate solutions) which are moved around the search space to find best solution using their positions. Each particle cooperates with the others during the search process by sharing the information of its current position with the best position that it and the other particles in the swarm have found.

Initially, a number of particles *N* of the swarm *xi* are randomly positioned in the search space and random velocities *vi* are assigned to each particle. Then, each particle is evaluated by calculating the objective function. Once the particles have been evaluated the values of the particle's best position *pi* and the global best position *g* are calculated. Next, the algorithm iterates until the stopping criterion is met; that is either an acceptable minimum error is attained or the maximum number of iterations is exceeded. In each *k* iteration, each particles position *xk*+1*i* and velocity *vk*+1*i* are updated following the next equations:

$$v_i^{k+1} = \omega \cdot v_i^k + c_1 \cdot r_1 \left(p_i^k - x_i^k\right) + c_2 \cdot r_2 \left(g^k - x_i^k\right)$$
$$x_i^{k+1} = x_i^k + v_i^{k+1}, \qquad (1)$$

where *ω* is a real constant called inertia weight, *c*1 and *c*2 are the acceleration coefficients that moves the particles toward the local and global best positions; and *r*1 and *r*2 are both random values uniformly distributed between zero and one. The process is repeated until the stopping condition is met; the final value of *gk* represents the optimum solution found for the problem optimized using this algorithm. This module is in development.

For example using this module we choose the following figure, created randomly (no base);

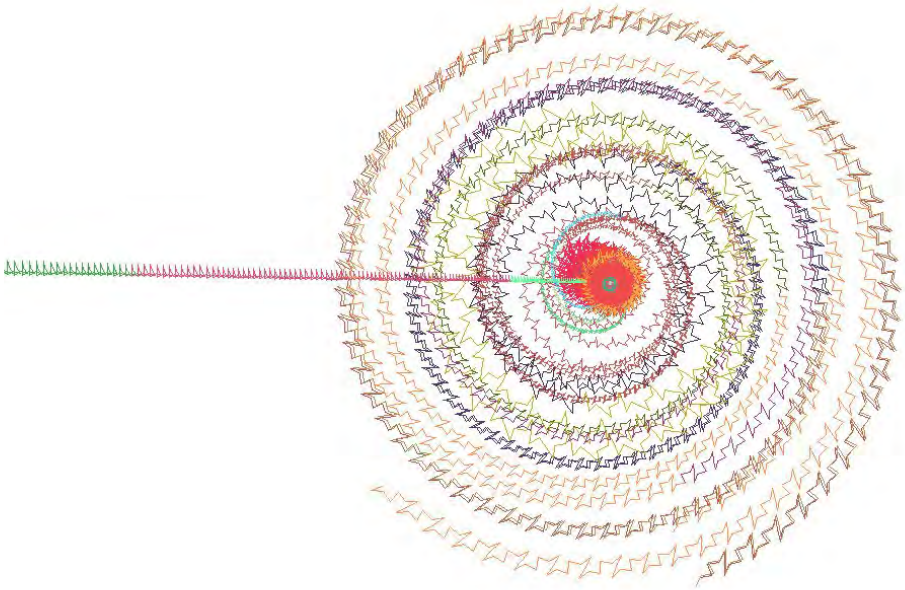

Figure 28 Randomly generated Image.

Using the coefficients to create this picture, we create a series of images (Figures 29-31).

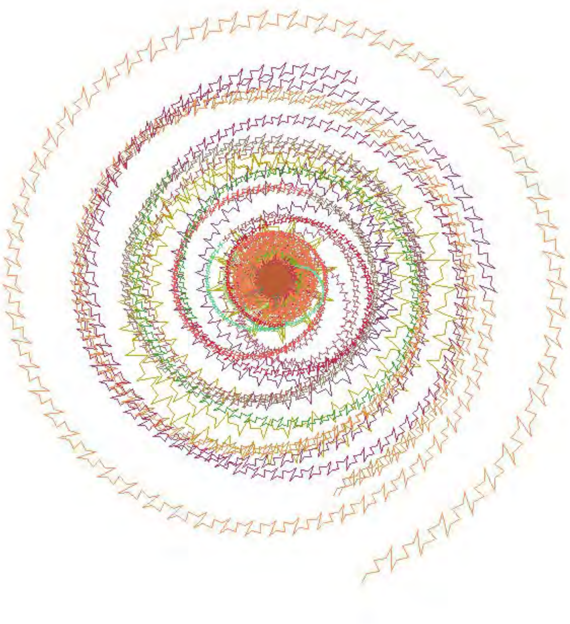

Figure 29 A.I. I

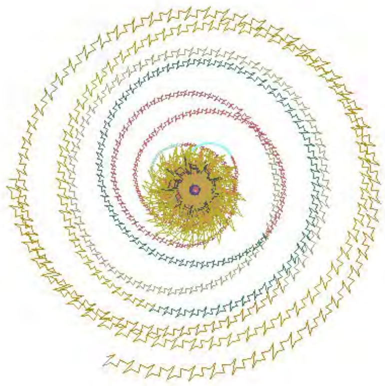

Figure 30 A.I. II

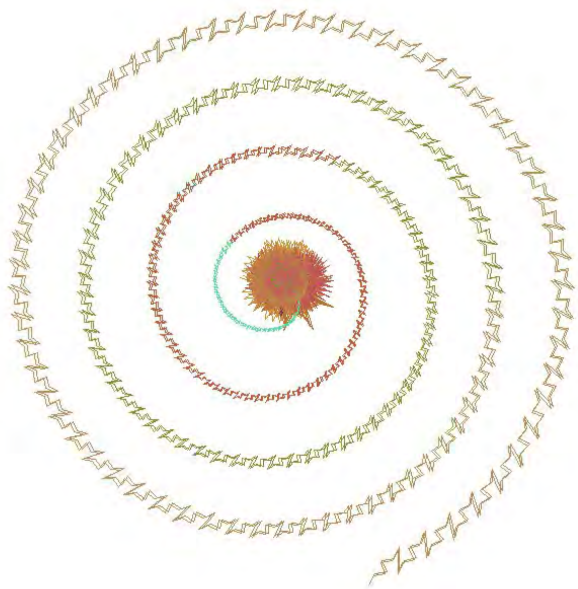

Figure 31 A.I. III

5. Acknowledgements

I would like to thank the Institut de Mathématiques de Bordeaux (Université Bordeaux Segalen), Galerie MLS, and the artist Gildas Bourdet.

6. References

[1] Gildas Bourde “*Peintures et Dessins*”, CASTA DIVA, Paris, 2012.

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