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The Breathtaking Algorithmic Art

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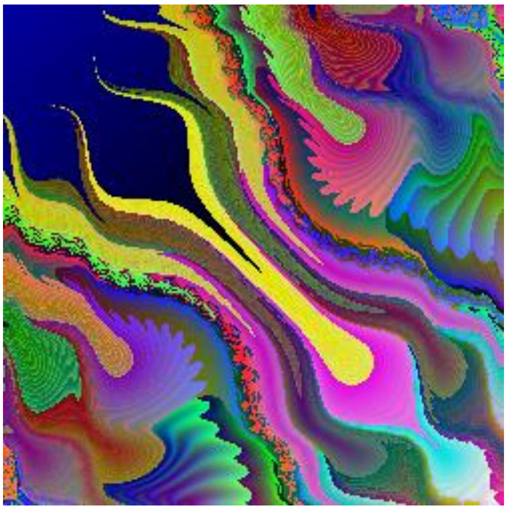
Abstract

An overview of Algorithmic Art (AA) and its dependence on computers is presented; it is clearly specified that AA uses mathematics although it is not always explicitly mathematical. Some technical details involved in the creation of images of AA are detailed. The fact that some impressive AA images created with early personal computers and, which are now impossible to reproduce due to the current super speed of PCs, is highlighted.

Keywords: Art, mathematics, algorithms, computing, Digital.

Algorithmic Art as an expression of Digital Art

Algorithmic Art (AA) is one of the several manifestations of Digital Art or Art by Computers, which owes its existence to that of computers. Among the expressions of the AA are the beautiful and stunning images created from computation protocols (algorithms) on mathematical expressions as equations, formulas, logical rules, etc.



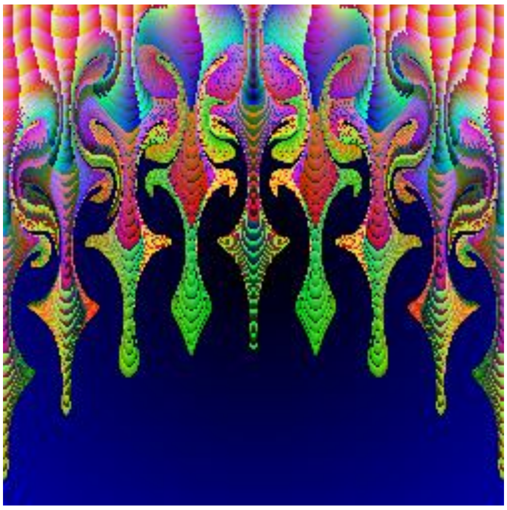
Algorithmic art makes use of mathematics

AA however, is not limited to the mathematical evaluation of equations; the AA use math just as what they are, a tool. For example, in those pictures that result from the replication of a transformation, this is repeated very many times. And while it is true this replication is run by a series of mathematical transformations, the end result is not essentially mathematical.

As an analogy, consider the design of an aircraft. Mathematics is required to calculate the power of the engine and its relationship with the weight of the same aircraft and the load that it will transport and the resistance of the materials to be used in its construction. Even more, in the case of a high-performance jet, its aerodynamics is calculated with mathematics but based on physical principles. However the plane is not a product of mathematics, although it may be of physics. The same applies when calculating an anti-seismic structure of a modern building.

Computers are essential for AA

Computers are indispensable to create works of AA, because with them it is possible to operate quickly and with no errors, on all the pixels (points of the plane) that make up the image.



It is very important to keep in mind that not all images of algorithmic art must be colored; many could be in strictly black and white, especially those that are based on geometric transformations. However, if the image is colored, the color of each pixel should be calculated. For example, a 60 cm x 60 cm image with a rather low density (90 pixels/inch), has about 4'665,600 pixels, and when creating the image, the color of each one of these pixels must be determined. The higher the resolution (pixels/inch) the better the image quality, because the image includes more information, more detail.

In some algorithms a formula or mathematical equation is used to calculate the color of each pixel and in these cases the image generation is rather quick and simple. In other algorithms the color is obtained by operating on mathematical or logical expressions several times, making a slight variation each time and in this way generating the corresponding graphical representation, this requires iterations, that is, processing several times each pixel across the image and, obviously this modality demands more computer time and greater number of calculations. Obviously, to run all this work manually, i.e., without computers, would result extremely tedious, slow and subject to errors.

In general, the beauty and visual impact that produces an image is completely independent on the number of calculations to obtain it or on the complexity of the algorithm that generates it.

The beauty of mathematics

In the past, before the Algorithmic Art, it was common to hear about the "beauty of mathematics", especially in those universities where sophisticated mathematics was handled in one way or another. Then the beauty of mathematics referred to the elegance and perfection of some of its topics, features which not all areas of mathematics possess. Nobody foreshadowed then that "The beauty of Mathematics" would apply in the future to the creation of beautiful and stunning images, abstract and not so abstract, symmetrical and not so symmetrical.

The experience of the author (JMJ) of this document is that some mathematical expressions (equations) really hide beauty. The challenge is to identify or build these equations and create a method (algorithm) to extract and visualize that beauty. It is the case of the images shown in this document, JMJ had to design the corresponding equations and create the algorithm to externalize the beauty that these equations kept hidden.

If someone devises how to extract the information that some equations hide, he will discover amazing symmetries in them, he will even identify some mathematical expressions that convey no symmetry but are impressive.

Images from the viewpoint of computers

Computationally speaking, an image is a three-dimensional matrix of components (x, y, z), whose first two components x and y indicate the position of a point in the plane of the image, and the value of z indicates the color that appears at that point. The value acquired by z depends on the algorithm that is applied to create the image.

In strict black and white images, the value of z can acquire either of two values, 0 or 1, representing white or black, respectively. In grey leveled images, z can take any value between 0 and 255, which makes 256 possible shades of grey between strict black and strict white. In color images, one of the most common color representations is the RGB (Red, Green, Blue), indicating the combination of shades of red, green and blue that may be stored in each z. In this case z has 3 components: R, G and B. Each of these 3 colors can take any value between 0 and 255. This makes a total of

$256 \times 256 \times 256 = 16'777,216$ possible colors in each z, this is, in each pixel (x,y) of the image. Note that although the human eye is unable to identify this millionaire amount of colors, the algorithms are able to generate them, and in practice when working with colors, it is very likely that all of them are be generated; unhappily that high color resolution is impossible to detect with the naked eye. Color images included in this document might include the millionaire amount of mentioned colors, but human eyes are not prepared either to distinguish them or to identify them.

As an example of the RGB representation, consider color RGB = (128, 200, 86). In this case the color is one that results from combining 128, 200 and 86 shares of red, green and blue, respectively.

Shocking images as a result of logical transformations

As already mentioned the images of AA are not necessarily the result of mathematical calculations. Some stunning and interesting images result from logical protocols, in which logical transformations, such as translations, rotations, changes of scale, etc, take place. Obviously these transformations are made through mathematics, but the essence of the transformation is not mathematical, it is logical. A simple example of a logical transformation is the one that consists in placing three dots around the place where before there was only one dot, next rotate and resize the set. This protocol may be replicated several times, depending on the algorithm. The procedure is executed with mathematics, but the operation is logical. This simple operation is the basis of tessellations (generation of amazing mosaics).

Traditional graphic artists paint images with the help of utensils like paintbrushes, sharpened canes, rags and nails; they use these implements as painting tools. Some artists even use their own blood to paint. Similarly, Algorithmic Art uses mathematics as a tool.

Algorithmic art techniques

Not all the techniques used to create works of AA, were created expressly for that purpose, many techniques have been adapted from other areas such as physics, biology, mathematics, etc.

Some well-known techniques that are commonly used to create works of algorithmic art are Generative Art, fractal modeling, Iterated Function Systems, Cellular Automata Tesellations, Polar inversion, Recursion, etc.

Obviously there must be some other techniques of AA, which are not known and are therefore of very limited use. In these cases, only the creator of the algorithm can use it to create images, which can be stunning and with great visual impact.

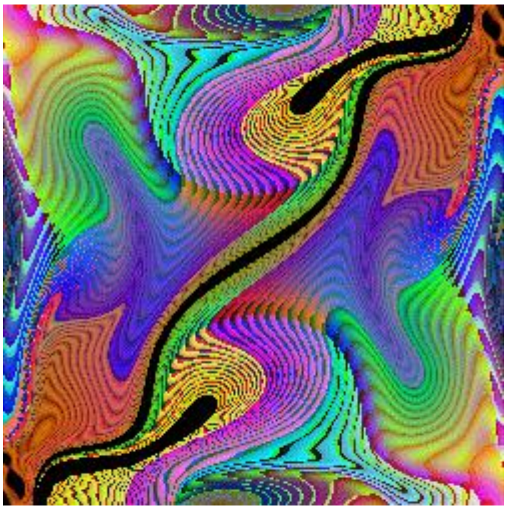
Time Evolution as AA

Some works of algorithmic art are evolutionary. They show the time-evolution of certain silhouettes, shapes and colors. The final resulting image could be very interesting and visually shocking, but the series of transformations taking part in their generation, this is, the evolution that generates the final product, may also be fascinating. This may be appreciated when the author of the artwork makes the computer to slowly execute and display graphically on the computer monitor the results as time elapses. For this reason an algorithmic artwork can also be rendered as a film or video.

Some artworks of AA are nowadays impossible to re-create

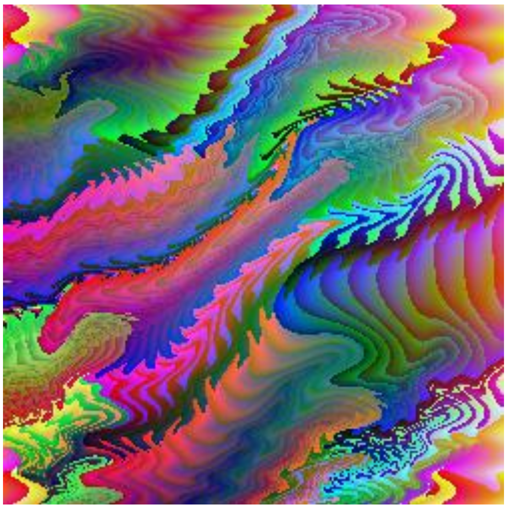
There exist certain old cinema films -which are true jewels of cinematography- that have been lost because they cannot be reproduced any more. Due to some technical reason it is impossible to render them in current video formats. The same happens with some artworks of algorithmic art.

Since the advent of computers, especially the personal ones, the creators of AA in the whole world have created some really impressive images, which are literally unique because they cannot be reproduced anymore, unfortunately they cannot be any longer copied or re-created. The main reason is that the current computers are too fast and do not allow old algorithms to be executed. In cases like these, attempts were made so as to adapt the old algorithm to modern technology, but this has not always worked.



Years ago, when the operating system of personal computers used to be the DOS (Disk Operating System), authors of computer art created some amazing images. As time went by, the upgrading of computers switched from DOS to Windows and Linux; but these modern operating systems are super-fast compared to DOS and, as a consequence the early algorithms created for DOS could no longer be executed. As a result those beautiful images created under DOS were lost, some still exist nowadays but cannot be re-created, literally. In some way more than a few of these images are like those classic paintings which art collectors and museums would like to possess.

Sometimes the situation is even worse, because from the impressive images created under DOS, only a remembrance remain today. In these cases not only the printing has been lost, but even the algorithm has been lost.



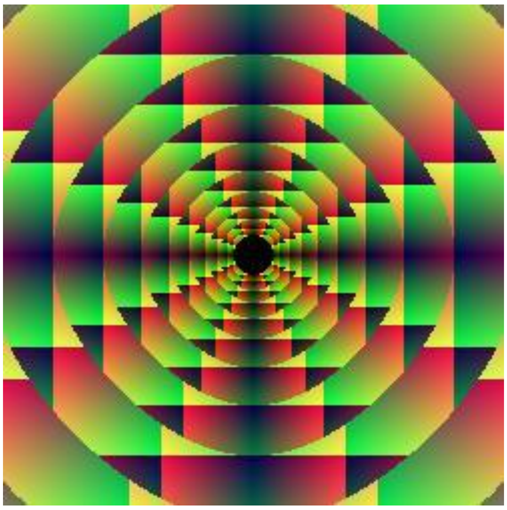
In the past due to the slowness of computers, if desired, it was possible to display on the monitor the step-by-step evolution of an algorithm; then it was possible to interrupt the development of an image and get some extraordinary image that eventually showed up on the way towards the objective image. Currently modern computers execute algorithms so swiftly that its author only sees the final image it creates. Obviously, this is a point where the impressive speed of modern computers has disadvantages.

As an interesting example, many years ago the author of this document, created an algorithm showing on the monitor of the computer, the evolution of a group of ellipses that were rendered as a knot of random colored ellipses. This was created in DOS which now is no longer used as it is very slow for today's computing standards. Nowadays to execute this algorithm, it has had to be adapted to modern fast computers and, even when executed very slowly, it turns out very quick to the human eyes, and only the final knot is appreciated. In this case the captivating beauty of the algorithm used to be the visualization of the slow step-by-step evolution of the knot of ellipses and, this has been lost.

The images included in this document

Images included in this document have all been created with algorithms developed expressly for AA by the author (JMJ). Here images are small, low-resolution and in compressed format, so its quality is not optimal. When any of these images is to be printed, it is developed to measure not less than 60 cm x 60 cm, and in non-compressed format so that it has a very high quality.

Some of the images included in this document are symmetrical, others show inverted symmetry (they are anti-symmetric) and yet others have no symmetry at all, some are even abstract. Obviously in order to create these images each one of them had to be planned before its development. If the image was to be symmetrical, details associated to symmetry had to be included in the algorithm, when anti-symmetry was the objective, an algorithm that introduced inverted symmetry had to be included in the development of the image. All the process is like the one followed when constructing a house to dwell in her.



Sometimes, and just like when an architect constructs his own house, some modifications were introduced at construction time. These modifications were added because the obtained images were not as fascinating as the expected ones. The colors and degrees of contrast among them were also calculated and they were sometimes modified as well, so as to achieve a more impressive and captivating image.

Conclusions

This paper has signaled that the algorithmic creation of images depends strongly on both, computers and mathematics. The fact that mathematics is used to communicate computers how to proceed so as to create an artwork does not necessarily mean that algorithmic artworks are in essence, mathematical; indeed, many times these images are result of analogical transformations. This paper has mentioned some known techniques used to create algorithmic art images; also some technical details involucrate in the planning and the development of digital images have been exposed. It has been explained why due to the high speed of modern computers, many algorithmic artworks, created originally in ancient DOS, definitively disappeared, since they cannot be reproduced anymore.

This document is an adaptation from the original in Spanish.

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The author

Javier Montenegro Joo is a computational & Simulational Physicist who in his spare time develops algorithms to create images.