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ArtiE-Fract, used by Anabela Costa, visual artist

Evelyne Lutton[1] & Anabela Costa[2]

[1] AVIZ Team, INRIA Saclay - Île-de-France, Bat 490, Université Paris-Sud, F-91405 ORSAY Cedex, France
Evelyne.Lutton@inria.fr
[2] http://www.anabelacosta.com/ http://wwwanabelacostacom.blogspot.com/
anabelacosta@msn.com

Abstract

The video artwork "Landscape" created by the independent filmmaker Anabela Costa is based on an original exploitation of the interactive evolutionary design software ArtiE-Fract. Initially dedicated to static shape design, ArtiE-Fract is based on an interactive Evolutionary mechanism that helps an artist or a designer to explore a space of 2D fractal shapes. Since its first version, it has been used by various artists and designers, mainly for the design of textile motives and posters. Anabela Costa fully exploited the morphing utilities provided by ArtiE-Fract, to produce videos. She pointed out new potential uses of this design tool.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—

1. Introduction

Fractal pictures have always been considered as attractive artistic objects as they combine complexity and "hierarchical" structure [Bar88, Hut81], and provide a simple way to generate shapes that look "natural". Born from the analysis of "strange" mathematical objects (such as an infinite length curve embedded in a finite surface, or as a continuous functions nowhere differentiable) at the end of the XIXth century, the so-called Fractal geometry became famous with the work of Benoit Mandelbrot [Man77] in the middle of the XXth century. The main argument was that these mathematical objects were convenient models to represent natural shapes: fern, coast of Britanny, romanesco caulifower, are examples of natural fractal shapes.

ArtiE-Fract is based on Iterated Function Systems (IFS), a model of fractals that became famous in image compression applications [BD85], but that has many other applications (for example in speech signal processing [DLV94]). The mathematical structure of iterated function systems attractors [BD85] let some more or less direct access to its characteristics and therefore, shape manipulation and exploration is possible [FMV98, RLCS99]. The IFS model is also very convenient for building nice continuous morphings.

In ArtiE-Fract, an Interactive Evolutionary Algorithm (IEA) is used as a generator of fractal pictures with controlled randomness. This interactive approach is not new in computer graphics [TL92, Sim91], but has been extended to the exploration of a fractal pictures space based on nonlinear IFS. A special focus has also been set on flexibility with the help of advanced interactive tools related to the specific fractal IFS model that is used.

ArtiE-Fract is the result of a quite long maturation process, a common work with engineers, artists and designers to provide a set of user-oriented tools. It intends to approach the interactive efficiency of a "photoshop" or a "gimp" software (of course in its own domain, that is fractal images design) .

2. Artificial evolution for artistic and design purpose

Artificial Evolution is the generic name of a large set of techniques that rely on the computer simulation of natural evolution mechanisms. Since the pioneering works of Alex Fraser [Fra57], Hans-Joachim Bremermann [Bre62], and after them, John Holland [Hol62, Hol75] and Ingo Rechenberg [Rec73], Artificial Darwinism techniques have progressively gained a major importance in the domain of stochastic optimisation and artificial intelligence.

The basic idea of this set of algorithmic techniques is to copy, in a very rough manner, the principles of natural evo-

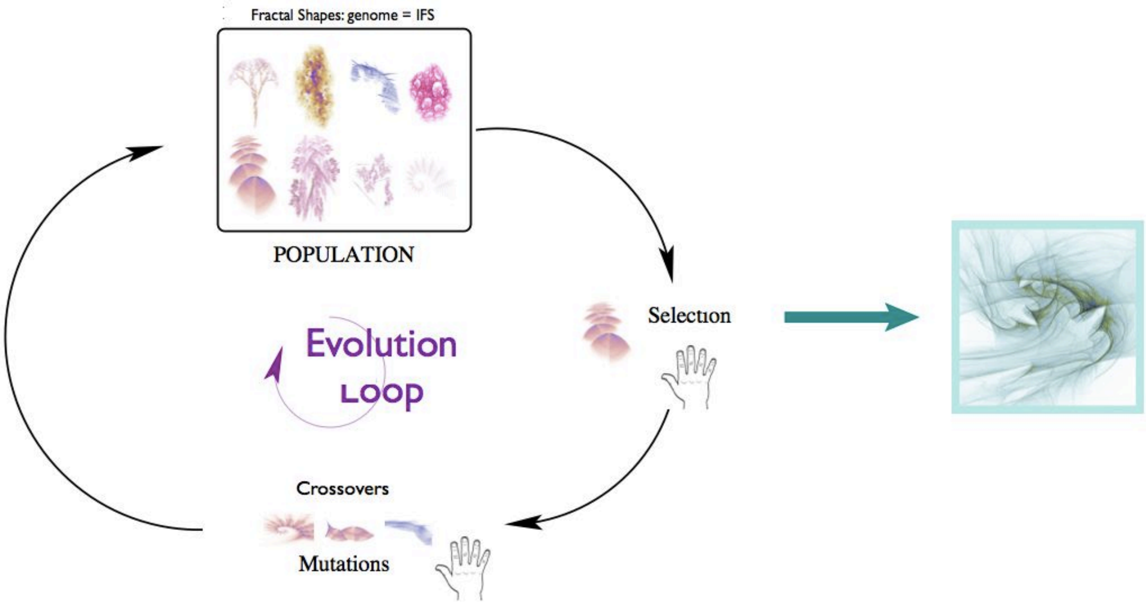

Figure 1: *ArtiE-Fract: an evolutionary loop with human interaction. Candidate images are considered as a population submitted to external pressure (aesthetic evaluation), that reproduces by mutation and crossover to built a new generation, displayed to the user via an interface.*

lution, that let a population be adapted to his environment. According to Darwin's theory, adaptation is based on very simple mechanisms: random variations, and survival / reproduction of the fittest individuals. Computer scientists have transposed this scheme onto optimisation algorithms, that have the major advantage to make only few assumptions on the function to be optimised (there is no need to have a continuous or derivable function for instance). In short, Evolutionary Optimisation considers a population of potential solutions exactly as a population of individuals of a natural population that live, fight and reproduce. The environment pressure is replaced by an "optimisation" pressure: the function to be optimised is considered as a measurement of the adaptation of the individual to its environment. In this way, individuals that reproduce are the best ones with respect to the problem to be solved, and reproduction consists in generating new solution via a variation scheme (the genetic operators), that, by analogy to nature, is called mutation if it involves one individual, or crossover if it involves two parent solutions.

Evolutionary optimisation techniques are particularly well suited to complex problems, where classical methods fail, due to the irregularity of the function or to the complexity of the search space. The versatility of the evolutionary framework has produced a variety of different optimisation techniques for various purposes (multi-objective, interactive, cooperative), aimed at exploring different search spaces (discrete, combinatorial, continuous, tree-based, graph-based, grammar-based, constrained, limited or infinite). The major reason of this success is the tuneable combination of oriented and random search mechanisms embedded in an evolutionary algorithm, that allow injecting a priori, incomplete, informations in the genetic operators, while letting some other more unpredictable components be randomly searched.

The versatility of the evolutionary scheme allows considering the optimisation of "non computable" quantitites, like subjective or aesthetic judgments. This is at the basis of what is called interactive evolution or more broadly, humanized evolution [Tak98]. Interactive Evolution corresponds to evolutionary algorithms where the evolutionary process is constrained by an interaction with a human user. In classical optimisation schemes, the algorithm has only access to a parameter space with no special signification, except the one embedded in an automatic fitness function. Subjective evaluation provided by a human end-user may replace or complement this automatic fitness function, but interaction may also occur in each component of this system (initialisation, evolution, selection, genetic operators, constraints, local optimisation, genome structure variation, parameters setting).

Figure 1 gives an overview of the basic evolutionary principles used in ArtiE-Fract : interactions with the designer occur mainly via fitness evaluation and genome modifications. A complete description of ArtiE-Fract and of some of its usages can be found in [CL01, LCC03, Lut06] or at `http://cetoine.fr`. We focus below on the main features that were used by Anabela Costa.

3. Interaction with the user

Interaction with humans usually raises several problems, mainly linked to the "user bottleneck" [PC97]: human fatigue and slowness. The solution proposed with ArtiE-Fract is a variety of interactions, that avoid repetitive and boring interactions, and allow the user focussing at various characteristics he can control.

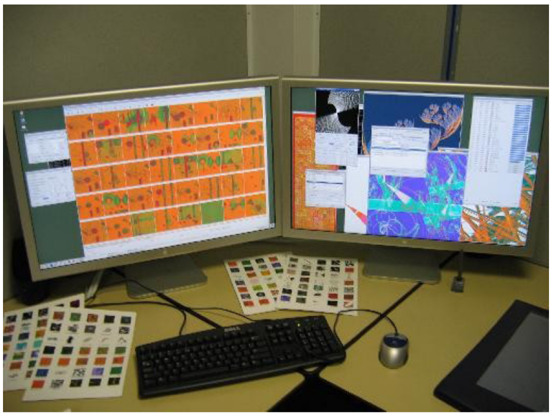

Figure 2: *ArtiE-Fract used for still images design: the population is displayed on the left screen, and individuals are visualised and manipulated on the right screen.*

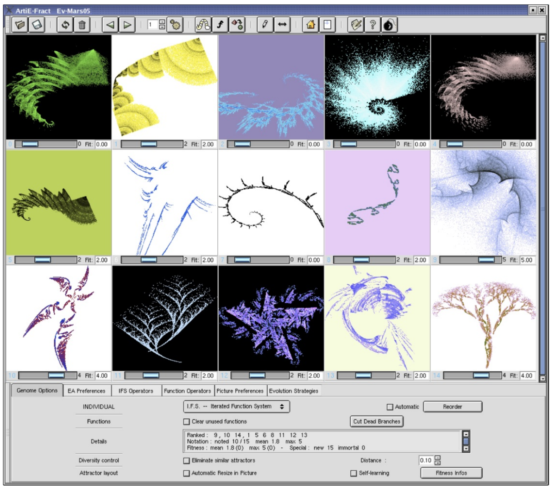

Figure 3: *Main Window of ArtiE-Fract.*

Allowing direct interactions on the phenotype's level represents a further step toward efficient use of IEA as a creative

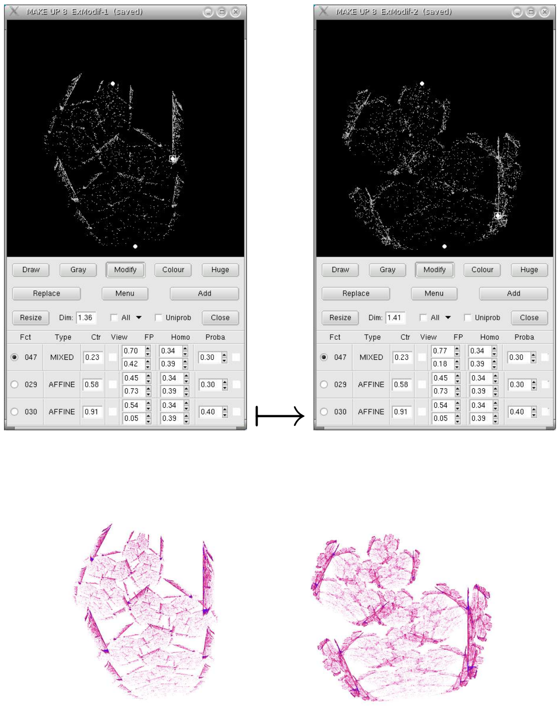

Figure 4: *User-driven mutation: a specialised window (top) allows interactively moving some control points of the IFS attractors. The right control point (highlighted) is moved down, the resulting attractors are displayed in color (bottom).*

tool for artists. The idea is to make use of the guided random search capabilities of an EA to *aid* the creative process. This is why in ArtiE-Fract, the user can interfere in the evolution at different levels:

- *initialisation*: various models and parameters ranges are available, with some "basic" internal fitness functions (image density, for example);
- *fitness function*: at each generation, a classical manual rating of individuals is available, see figure 3, the user can also destroy individuals or re-introduce an old individual;
- *direct interaction with the genome*: images can be directly manipulated via a specialized window and modified individuals can be added or replaced in the current population (it plays the role of a sort of interactive "local" deterministic optimisation). A large set of geometric, colorimetric and structural modifications are available. Moreover, due to the specific image model, some control points can be defined on the images that help distort the shape in a convenient, but non trivial manner, see figure 4;
- *parameter setting and strategy choices* are tunable at any moment during the run.

4. The IFS model as genome

ArtiE-Fract allow an exploration of the space of 2D fractal shapes encoded as iterated function systems (IFS). This represents a wide variety of shapes, that may appear more or less as “naive fractals.”

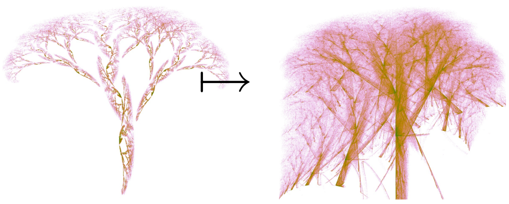

Figure 5: *A random mutation.*

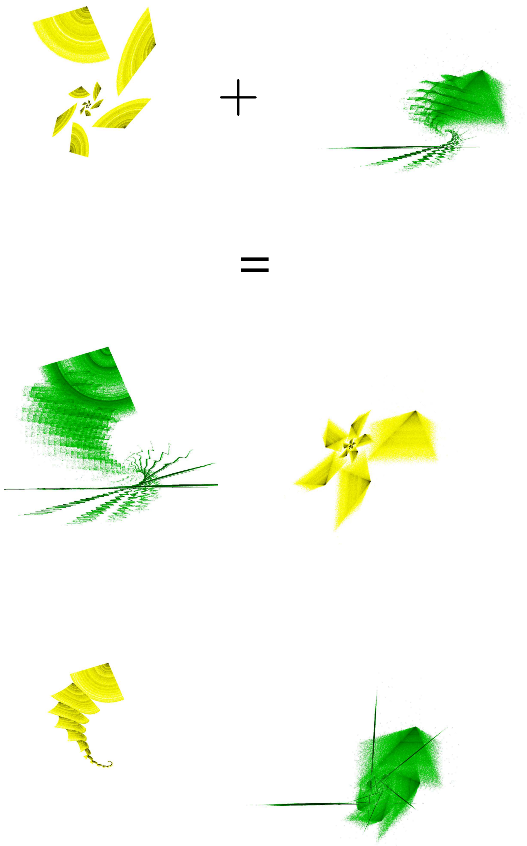

Figure 6: *Four possible crossover offspring (bottom) from 2 parents (top).*

A population of pictures is displayed to the designer (figure 3), but the objects manipulated by the interactive evolutionary algorithm are actually dynamical systems (IFS, whose attractor can be represented as a 2D picture). These IFS are encoded as sets of contractive non-linear 2D functions (affine and non-affine), defined either in cartesian or polar coordinates. The IFS are then evolved using specific tools (Genetic Programming engine, for instance [Koz92]). Examples of random, or guided, crossovers and mutations are presented in figures 5 and 6.

From an artistic standpoint, affine IFS give access to an interesting variety of shapes (the “self-affine” fractals). But the use of non-affine functions yields a variety of shapes that may look “less directly” fractal. This is another of the specifics of ArtiE-Fract: three models of IFS are used (affine, mixed and polar), separately or in combination. Each of them induces a slightly different topology on the search space, which gives privileged access to various image types.

This additional freedom, based on the use of non-linear functions seems to be experimentally attractive to artists, as it allows the expression of various inspirations.

5. The morphing utility

The IFS model is very convenient for builing continuous transformations between attractors. A simple interpolation formula, based on a linear combination of the functions of each attractors, allow building a set of intermediate IFS of any length, i.e. a continuous morphing between the two initial shapes, see figure 8. This operation is accessible for any couple of IFS of the current population, and produces a set of IFS that can be re-injected in the population for further evolution, or used for building videos.

Other tools for building image sequences are also available in ArtiE-Fract, for instance based on some continuous predefined movements of the control points, or based on zooming or probabilities modifications.

6. The work of Anabela Costa

Anabela Costa based her artistic research on an intensive exploitation of the video making utility of ArtiE-Fract (figure 7), going back and forth between the evolution window and the video making window, using outputs of interpolations as a fully controlled crossover operator for the evolved population. The artwork she presents were then finalised using an external editing tool for the final video edition.

The way she uses ArtiE-Fract let us revisit some constraints on IFS attractors that may be set *a priori*. For instance minimal density of images or size of attractors, that constrain the search to visually interesting images, has an impact only for still image. If we deal with moving objects, a very small attractor (or a set of points) may be considered as aesthetic, because of its movement perceived in a succession of images, and not because of its static shape.

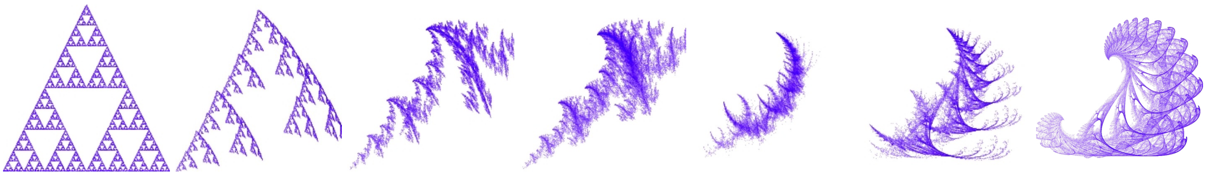

Figure 8: *An IFS morphing built with* ArtiE-Fract*.*

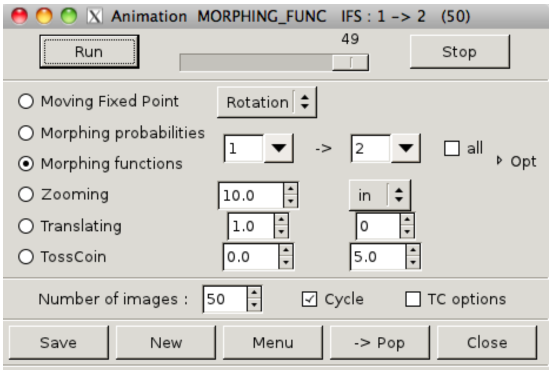

Figure 7: *The Animation window: various animation tools are available: linear morphing of functions, of probabilities, controlled movements of fixed points, zooming, or progressive computation precision (number of iterations of the tosscoin algorithm).*

Another important output of this work is related to the use of artificial evolution for video design: a straightforward strategy that consists in directly manipulating videos as genomes and displaying it in an interactive evolutionary algorithm was not what whished Anabela Costa for her artistic design. This strategy may be too constrained for the way she works. She used the evolution of still images as a source of raw material for her video montages (see figures 9 to 11), and the implicit fitness she actually used for evolving the population of IFS attractors is based on a indirect evaluation using the animation tool of ArtiE-Fract.

7. Elements for future developments of ArtiE-Fract

Besides straightforward extensions to other fractal image models than iterated function systems, like for instance nonlinear Julia sets or L-systems, some desired additional features are related to a closer control in interactions.

We will consider interactions based on the resolution of an inverse problem, that is trying evolve IFS that approximate a given shape. This may be directly useful in applications like logo design. The idea is to augment the control of the user with respect of the global appearance of the evolved shape, i.e. constrain the evolution of the shapes by a computed pressure toward an image provided by the user (collected via a graphical tablet for instance). The experiments conducted on video sequences generation let us imagine similar facilities for constraining the evolution of shapes to be used as components of a video animation. ArtiE-Fract already offers some tools to design trajectories of animation, but it is for the moment reserved to animations of a single IFS attractor. Constrained evolution will allow to extend this type of control on morphing animations.

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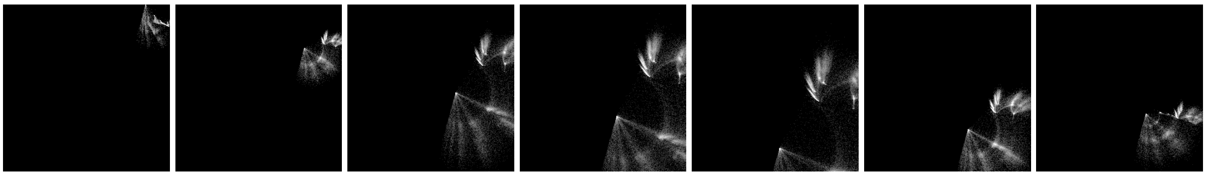

Figure 9: *A sample of a raw animation created by Anabela Costa, based on a movement of control points for a single IFS attractor.*

Figure 10: *A sample of a raw animation created by Anabela Costa, based on a linear morphing between two IFS attractors.*

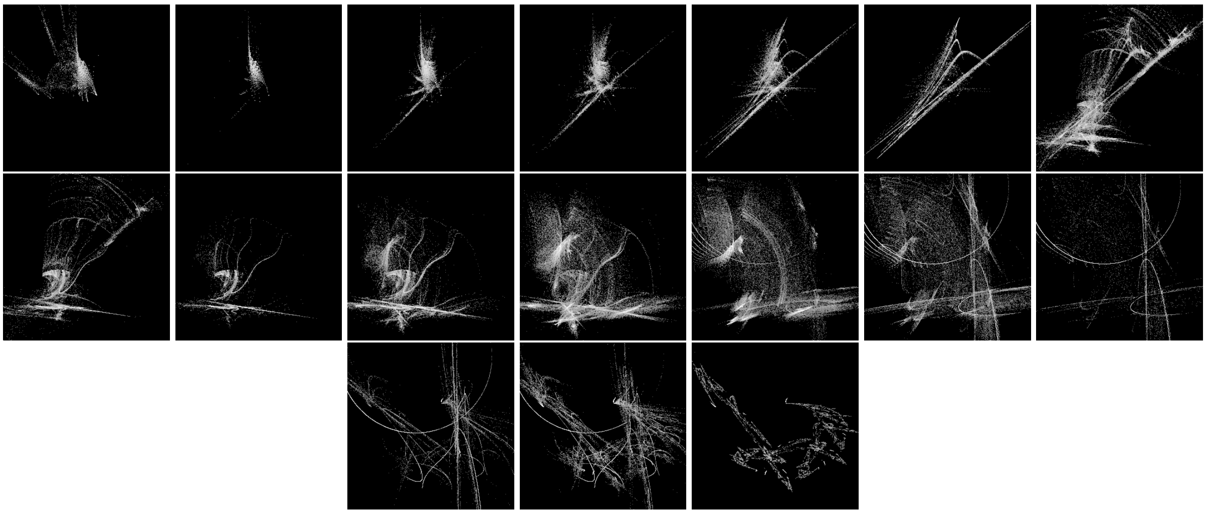

Figure 11: *A sample of a raw animation created by Anabela Costa, based on a morphing of probabilities using several IFS attractors.*

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