Evolving Families of Shapes

Filipe Assunção and **João Correia** and **Pedro Martins** and **Penousal Machado**
CISUC, Department of Informatics Engineering
University of Coimbra, 3030 Coimbra, Portugal
fga@student.dei.uc.pt, {jncor, pjmm, machado}@dei.uc.pt

Abstract

Visual families are seen as sets of artifacts that share common visual features allowing one to intuitively classify them as belonging to the same family. An evolutionary approach for the creation of such families of shapes, where each genotype encodes a visual language by means of a non-deterministic grammar is explored.

1 Introduction

Typically, when we observe a set of works from a given artist, or artistic movement, we naturally classify them as belonging to the same class, genre, or style. Often, the collection is more interesting than the individual works, revealing more information about the artistic goals, intentions and aesthetics of the author. To some extent, the work of artists implies creating a visual language and expressing themselves using the power, and constraints of that language. As the research of Stiny and Gips [1971] on Shape Grammars demonstrates, even when this language is not explicitly defined by the author, in some cases it is possible to derive and formally express the rules that capture the underlying principles of a set of artifacts (e.g. Frank Lloyd Wrights prairie houses), and then use this grammar to create new instances that are consistent with the author's artistic practice. This observation was the main motivation for the present work.

An additional motivation comes from the following observation, based on our work on interactive evolution of images: often, when we look at an evolved population, we find that it is more interesting as a whole than the images it contains when observed in isolation. This can be explained as follows, an evolved population tends to be composed of images that share a common genetic background, their genotypes tend to be similar and, as such, the images tend to share several visual characteristics. Therefore, each image is perceived in a context which is supplied by the others, and, as a whole, the images are perceived as variations on the same theme.

Most evolutionary art systems focus on the evolution of individual artworks, in the sense that each genotype is mapped into a single phenotype (e.g. image). Based on previous work of Machado et al. [2010a; 2010b] we explore the evolution of Context Free Design Grammars (CFDGs) [Horigan and Lentczner, 2014], which allow the definition of complex families of shapes through a compact set of production rules. Each genotype is a well-constructed CFDG that can be mapped into multiple images and, as such, encode a family of shapes.

The main contribution of our work is the proposal of a scheme to evaluate families of images. Whereas previous works on the same topic ignore the characteristics of the set of images created by each genotype, we consider: the quality of each image, the differences of quality among images, the consistency of the set and the diversity of the set.

2 The Approach

The evolutionary Graph-Based Genetic Programming engine used in this study is thoroughly discussed and tested in Machado et al. [2015] and is an extension of previous work by the same author [2010a]. Therefore, and due to space constraints, we will focus on the aspects regarding the evaluation of families of shapes. To that end we developed a fitness function that takes into account several aspects of the images and of the family. The principles that guided the development of this formula are:

1. The quality of each image belonging to the family should be maximized;
2. The differences in quality should be minimized;

We consider that these are necessary conditions, since a collection of images that are deprived of interest on their own or a collection composed of extremely good and extremely bad images cannot be considered a high quality family of shapes. These conditions are not, however, sufficient. For instance, a collection composed exclusively of the same high quality images would meet those two criteria, but it could hardly be found interesting. Thus, we must take into account the relations between the images of the collection:

3. A proper degree of diversity should exist.

Thus, the images should be diverse, to avoid monotony, but, at the same time, they should share some similarities, otherwise they would no longer be intuitively classified as belonging to the same family.

For each genotype we perform multiple calls to the rendering engine, with different rendering seeds, obtaining S, which is an ordered set of samples of the visual family. Then, we assess the quality, fit_{im}, of each image, I, in the sample, S, which allows us to compute the mean quality, $\overline{fit_{im}}$, and the standard deviation of the quality, $\sigma_{fit_{im}}$, thus addressing the first two principles we have enunciated.

To address the third principle, we calculate the similarity among all pairs of images belonging to the sample, sim, and calculate the average.

All the above allows us to propose a fitness function for the assessment of visual families that addresses the three aforementioned principles, as follows:

$$f(S) = log\left(1+\frac{\overline{fit_{im}}}{1+\sigma_{fit_{im}}}\right)^{a} \times log(1+N(sim(S),\mu,\delta))^{b} \quad (1)$$

where N is the normal distribution function. By establishing different values for μ we can adjust the desired degree of similarity, and by setting different σ values we may adjust the penalization for deviating from that desired similarity. The use of the log function prevents evolution from focusing exclusively in one of the components of the formula. Finally, the exponents a and b allow us to adjust the importance given to each component.

3 Experimental Results

In Machado et al. [2015] we used a combination of "aesthetic measures" adapted from evolutionary art literature to evolve CFDG images. We resort to one of these combinations to assess the quality, fit_{im}, of each image, I, in the sample, S. This particular combination focuses on the chromatic characteristics of the image, and uses two aesthetic measures: *Bell Curve* and *Contrasting Colors*.

In order to test the adequacy of the proposed approach, we performed several experiments with different parameters. In a first set of experiments, tests focusing on each of the components of the formula demonstrated that all of them played an important role. For instance, when the diversity of the family of shapes was ignored ($b = 0$), evolution typically converged to sets of images composed of repetitions of the same shapes or with minor variations among them. Conversely, when we only considered the diversity of the families ($a = 0$), there was no pressure to evolve images that were chromatically interesting, as such, it became trivial for the evolutionary algorithm to match a target diversity value using simple and uninteresting shapes.

After these preliminary tests, we focused on the analysis of the impact of diversity settings in the results of the runs, trying to find a compromise between visual consistency and diversity.

Figure 1 shows samples of families of shapes evolved using all components of formula 1. The first row depicts a family of shapes evolved with $\mu = 0.7$, illustrating how a high μ setting leads to the convergence towards monotonous families of shapes. The bottom row presents a family of shapes evolved with $\mu = 0.1$. As it can be observed, the high degree of diversity hinders the visual consistency, and the presented images no longer appear to be part of the same family. The middle row presents one of the families evolved with $\mu = 0.5$. In our subjective opinion, this setting yields the most promising results, consistently producing sets of images with an adequate degree of diversity.

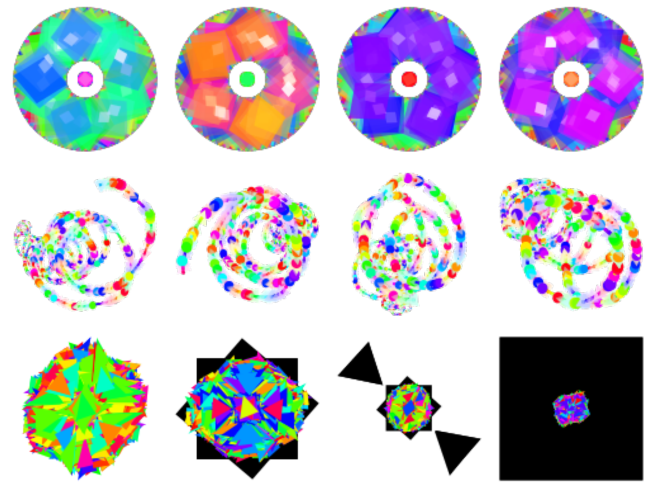

Figure 1: Samples of the fittest individuals from three independent runs. Each row presents samples of images produced by a single individual.

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