Creative Systems as Dynamical Systems

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Abstract. In this paper, we discuss ideas for characterizing a case-based generative system as "creative". Focusing on a specific generator of graphics, we performed a qualitative exploration of the space of solutions. The emerged intuition is that the set of configurations generated by the program can be viewed both as the conceptual space of a creative system and the phase space of a dynamical system. In the context of this analogy, we hypothesize that a higher degree of creativity can be ascribed to the search paths allowing the system to reach new basins of attractions.

1 Introduction

Case-based reasoning (CBR) is a type of problem solving in which a new solution is found through the retrieval of a similar available case and the adaptation of the related solution [1].

Let us suppose to have a computer program for the generation of artworks such as graphics, musical pieces, or poems, and a set of generative parameters. Given a set of known examples, a different initialization of the parameters should allow the system to produce different corresponding instances of the same type of artifact. However, the production of new artifacts does not necessarily imply that they would be recognized as original and valuable. In this paper, we discuss ideas for characterizing the re-use of past solutions, performed by a case-based generative system, as "creative".

An artwork generator can be framed in the context of ideas on *creative systems* introduced by Boden [2], formalized by Wiggins [12] and further extended by Ritchie [11]. In this context, the case-based adaptive process can be viewed as a type of *exploratory creativity*, i.e. a search in the space of artifacts or *conceptual space*, where the set of past examples are the *inspiring set*. Ideally, the output of the search should be an artifact provided with a form of value and expressing the balance between familiarity and novelty described by Giora as *optimal innovation* [4].

Focusing on a specific generator of graphics, we performed a qualitative exploration of its generative parameters, described in the next section. The rest of the paper discusses the insights inspired by this example.

2 Exploring the Space of Fractal Trees

We focused on an algorithm for the visual representation of a *fractal tree*, a fractal geometrical shape defined by recursion as follows: *(1) Draw a trunk; (2) At the end of the trunk, split by some angle and draw a prefixed number of branches; (3) Repeat at the end of each branch until a sufficient level of branching is reached*[1]. The original code of the program[2] was implemented in *Processing* programming language [10]. For the mathematical details, we refer the reader to Mandelbrot's treatment [8, pp.151-161]. The shape depends on the value of two parameters representing the angle between two adjacent branches and the rotation angle performed on both of them, respectively. Their values are associated to the two coordinates of the mouse cursor in the output window. In this way, moving the cursor in different points of the screen, it is possible to generate an unlimited number of configurations.

In order to show the set of possible configurations in a small portion of the output window, we modified the code in such a way to draw a small square and to map the configurations to the coordinates of its internal points.

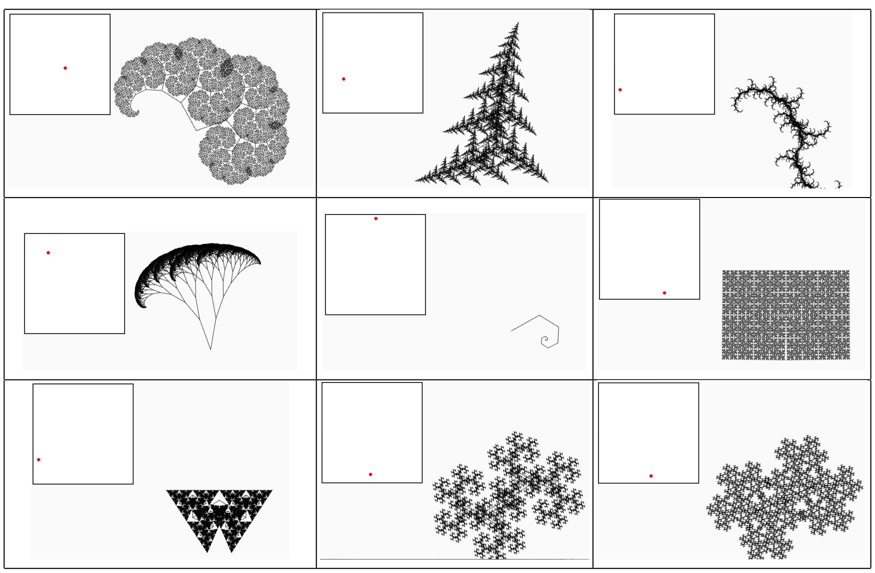

Fig. 1. Examples of configurations generated by the position of the cursor in different regions of the conceptual space mapped in the square.

[1] This version of the algorithm description is reported on `http://rosettacode.org/wiki/Fractal_tree`

[2] The code of the original program is available at `http://www.openprocessing.org/sketch/5631`.

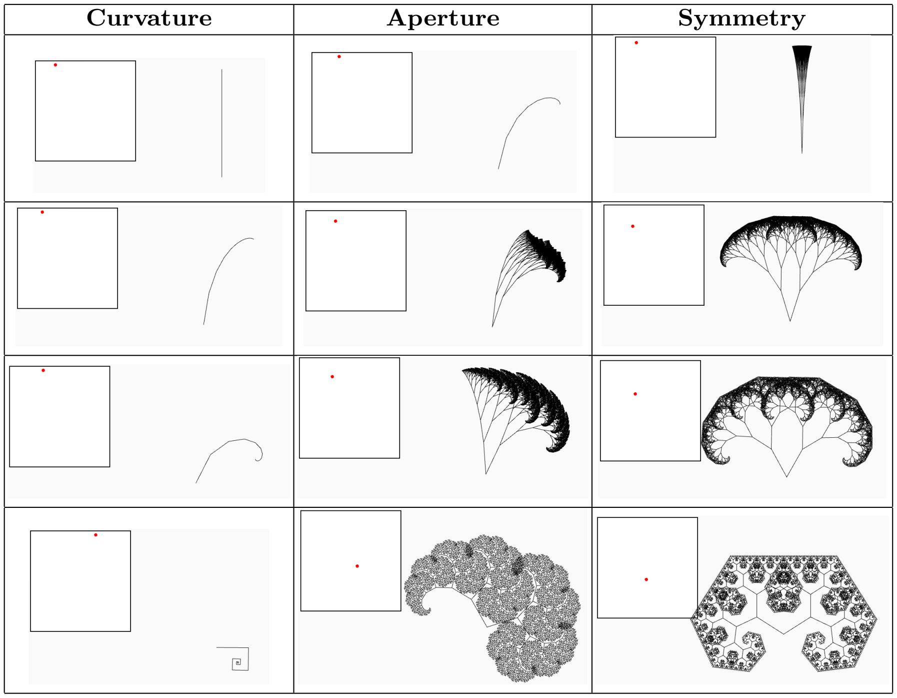

Fig. 2. Configurations according to different dimensions.

We observed the changes of the shape while moving the mouse cursor over the square. In doing that, we were inspired from a qualitative exploration described by Douglas Hofstadter in what he called an "exotic trip". He put his description in "*Gödel, Escher, Bach*" [5, pp.483-488] as a fictional dialogue and, three decades later, as a more detailed report [6, pp.65-69]. Hofstadter used a video camera pointed in various ways toward the output screen, and capable of generating several possible patterns. In particular, we made three main observations.

Shape Types Our first finding was that there are regions in the square corresponding to different types of shapes. As shown in Figure 1, some regions generate shapes recognizable as vegetable forms such as stone pines, firs, broccoli, or roots. Other regions generate polygons such as triangles, rectangles, or polygon spirals. Finally, there are regions associated to more complex shapes resembling snowflakes. Each region seems to correspond to specific *"natural concept"*, as defined by Gärdenfors [3].

Shape Dimensions The second observation is that, in each region, the shapes can be associated to a number of perceptual dimensions ascribable to Gärdenfors' *"quality dimensions"*. Specifically, we identified three dimensions: *curvature*, *aperture*, and *symmetry*. Each dimension seems to identify a specific trajectory in the conceptual space. Figure 2 shows some configurations according to the observed dimensions. Curvature and aperture can be easily defined in terms of the generative parameters. For example, since the overall figure is the superposition of a fixed number of broken lines, curvature can be defined as the angle formed by two adjacent segments in the broken line. According to the first column of Figure 2, the trajectory of curvature is a horizontal line. Moreover, aperture can be defined as the average difference between the curvature of two adjacent components. In the case of symmetry, the definition in terms of generative parameters seems more naturally definable "a posteriori", as a constraint on the generated shape.

Optimal Configurations Finally, the third observation is that, in each region associated to specific type of shapes, the aesthetic value of the shapes seems to change according to different generative parameters and dimensions. Furthermore, each column of Figure 2 shows that the aesthetic value seems to reach a maximum in correspondence of specific subsets of each region. These "optimal configurations" seem to be associated to specific ranges of curvature, aperture, and symmetry. At this stage of the research, this claim is proposed as an intuition to be formalized and empirically evaluated. In particular, it would be necessary to attempt a formal definition of aesthetic value in terms of the shape dimensions mentioned above. Moreover, an evaluation with human judges is needed to study to what extent there is agreement on the aesthetic values and their variation along the different shapes. Specifically, we intend to employ type of evaluation with subjects analogous to the one performed by Noy et al. [7]

3 Basin Jumping

If we consider a specific path in the square mapping the conceptual space, such that the variation of the aesthetic value is positive and reach its maximum in correspondence of the optimal configurations, we can view it from two different perspectives. On one hand, the path can describe a search session in the conceptual space of a creative system. On the other hand, it can be interpreted as a trajectory in the phase space of a dynamical system. According to the second interpretation, we can view each region of the conceptual space, associated to different shape types, as *basins of attraction* and their optimal configurations as the corresponding *attractors*. An attractor is a set of states (i.e., elements of the state space of a dynamical system) towards which a set of dynamical paths tend to evolve [9]. We go beyond the specific example described above and suppose that there is a large number of creative systems whose conceptual spaces can be decomposed in basins of attraction. Moreover, we hypothesize that the "creativity" of these system should not simply consist of the capability to generate the conceptual space and, starting from an initial configuration, explore its basin of attraction. Indeed, they should be capable of reaching basins of attraction not containing the past examples. In other words, if we assume the creativity as a search in the conceptual space, a higher degree of creativity is associated to the search of new basins of attraction.

4 Learning to Jump

The intuitions proposed in this work are aimed to identify a possible limitation in the use of CBR as a creative tool and to overcome it. A creative CBR system should get a the description of an artifact (i.e. an element of the conceptual space) as input case and retrieve one or more similar cases and reuse the corresponding knowledge to generate them. A possible intrinsic limitation is the use of similarity of past solutions. In terms of dynamical systems, we believe that this approach constraints the search inside a single basin of attraction. The suggestion emerged from the example described above is to identify perceptual dimensions and, through them, evaluation functions capable of reaching the maximum value in different basins of attractions.

In our next work, we aim to formalize, implement and empirically evaluate this approach. In particular, we intend to focus on generative systems analogous to the fractal tree generator and provide definitions of perceptual dimensions and aesthetic value. A crucial aspect is the combination of two types of heuristics, the first one for the discovery of new basin of attraction, and the second one for the identification of the optimal configuration.

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