In Search of a Perceptual Basis for Interacting with Parametric Images

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ABSTRACT
Many people appreciate the aesthetics of fractal images, but few are inclined to engage in the mathematics needed to create them. Finding a perceptual basis for interacting with parametric images like fractals could make the parameter space more accessible, which is an important step towards democratizing this creative activity. This paper discusses an experiment to gather perceptions of fractal images and compare them with computational analyses.

Autor Keywords
Human factors, design, perception, democratization, creativity

ACM Classification Keywords
H.5.2 User Interfaces (D.2.2, H.1.2, I.3.6); Evaluation/methodology, I.4.9 Applications

Genral Terms
Design, Experimentation, Human Factors

INTRODUCTION
Human reaction to different perceptual structures and the influence of contextual environment on perceptual behavior are some of the most interesting topics that concern psychologists and other scientists. Linear fractal images in particular, provide a rich source of stimuli within which to explore many questions of perception.

Can people without an understanding of geometrical transformations be empowered to generate their own linear fractal images (and animations)? If it is possible to understand how people perceive these images in relation to one another, a much more accessible interface for image creation could be developed, and user-generated content on video sharing sites, like youtube,[1] would follow.

This work seeks to examine this issue of similarity from both perceptual and computational perspectives, with the hope that they can inform each other.

LINEAR FRACTAL IMAGES
Since *The Fractal Geometry of Nature* [4] computer generation of fractal imagery has remained a popular activity. The images that we study are visualizations of the attractor of an iterated function system or a linear fractal [2], defined by 2 transformations, each of which specifies rotation (1 angle), scaling (2 values, for x and y), and translation (2 values, for x and y). Therefore, 2 transformations have 10 parameters. It is not difficult to imagine wanting to explore a minimum of 10 values for any of these parameters, which yields 10,000,000,000 potential images. Many of these images would be similar to one another, yet this is difficult to determine algorithmically.

HUMAN PERCEPTION OF SIMILARITY
Selection and number of stimuli is one of the most important concerns in designing a study. Bonebright et al. [1] suggest an actual task time not longer than 30-40 minutes. To make a thorough comparison of a set of stimuli, the rater should make judgments about all possible pairs – which is simply not feasible in all but simple situations. For this reason, much effort has been placed on developing games as a way to encourage crowd-sourcing of data [3].

In order to make our stimulus set manageable, we chose to hold constant the scaling and translation parameters and to increment the rotation angles by 3.6 degrees, leaving a stimulus set containing 10,000 images (100x100).

Each one of 25 participants saw 1600 images, divided into 16 sequences of 100 continuously-varying images (8 unique sequences, shown forward and backward). Following the method of limits [5], each participant was asked to make judgments about when the change was noticeable, in each of two directions. The interface for this task is shown in Figure 1. Sample data, with analysis, is shown in Figure 2.

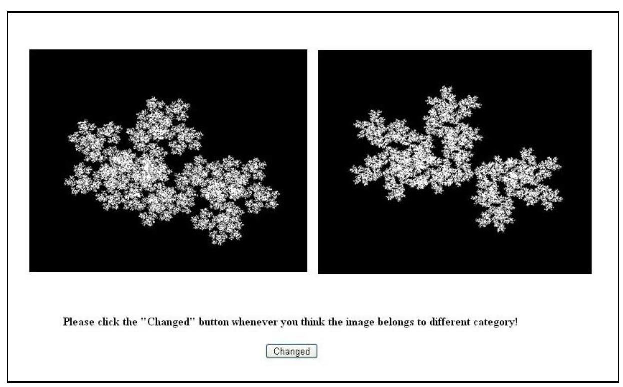

Figure 1. The participant's task was to click the "Changed" button anytime they felt that the left and right images were noticeably different.

[1] http://www.youtube.com

C&C'09, October 26–30, 2009, Berkeley, California, USA.
ACM 978-1-60558-403-4/09/10.

COMPUTATIONAL SIMILARITY

To develop a reference point for the perceptual study, both local and global measures of image similarity were computed.

Local

Mean squared error (MSE) [7], one of the most popular methods for image comparison, was used to measure the pixel by pixel variation between 2 adjacent images. Just as the participants had done in the perceptual experiment, this metric was computed for both forward and backward comparisons. For all but the first and last image in a sequence, the 2 computed values were averaged. These values are plotted on the top line in Figure 2.

Global

Following the eigenface approach of Turk and Pentland [6], a principle component analysis of the images was performed. A procedure outlined by Dailey[1], for MATLAB[2], took the two diagonals of the 100x100 image grid as input. From the vectors output, the top 40 were used and accounted for 85% of the variance in the images. All 10,000 images were then expressed as coordinates in this 40-dimensional space. Within each image sequence, Euclidean distance between neighbouring images was computed. Values were normalized over the entire sequence. Figure 2 (2nd line from top) shows the results for one image sequence.

ANALYSIS

Data from the perceptual study was noisy. Lines 4 and 5 in Figure 2 show the clicks in the forward and backward directions, respectively. Some clicks appear in the same general location both times, but many others do not. In order to combine the click data from both viewing directions, the following procedure was used: images between the same clicks were considered to be similar while images between different clicks were considered to be dissimilar. With this information, pair-wise distances between all images were found and then used to perform a multi-dimensional scaling analysis in R[3]. Euclidean distances were computed between adjacent images, and shown in Line 3 of Figure 2. Peaks indicate a perceived change between images – differing heights of peaks could be interpreted to indicate different levels of certainty. The two vertical lines in Figure 2 show the correspondence between the maxima of the PCA (left) and MSE (right) and the participant's clicks. The participant here has clicked in the neighbourhood of each of the maxima.

FUTURE WORK

More participant data for the perceptual study will be collected in the lab to better understand the possible roles of individual differences, different rating strategies, and other factors in determining perceived relationships between images. Do some people see with more detail than others, or do they see differently than others? It is hoped that results here can guide exploration of the 10,000,000,000 image set and beyond.

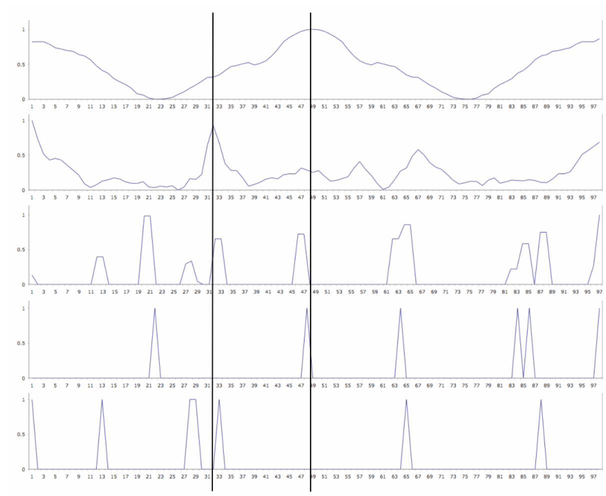

Figure 2. A comparison of perceptual and computational data. 1st line: MSE values (local) ; 2nd line: PCA values (global); 3rd line: click zone locations, computed from the following 2 lines; 4th line: clicks in forward direction; 5th line: clicks in backward direction. Vertical lines placed at maxima for PCA (left) and MSE (right).

ACKNOWLEDGMENTS

The authors wish to thank the Natural Sciences and Engineering Research Council of Canada, the Canada Foundation for Innovation, the Saskatchewan Innovation and Science Fund, and the University of Regina.

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[1] http://www.cs.ait.ac.th/~mdailey/matlab/

[2] http://www.mathworks.com/products/matlab/

[3] http://www.r-project.org/