

The Void Series — Generative Art using Regulatory Genes

Gary R. Greenfield
Mathematics & Computer Science
University of Richmond
Richmond, Virginia, USA

December, 2004

Outline.

- I. Introduction.
- II. Regulatory Gene Model.
- III. Cellular Morphogenesis Simulation.
- IV. Automating Aesthetic Evaluation.
- V. The Void Series.
- VI. Conclusions.

I. Introduction.

Objective. Use simulation of cellular processes to create 2D aesthetic abstracts.

Aesthetic Goals. Macroscopic and microscopic:

- Contemplate the mysteries of cellular development.
- Think about the complex dynamics of interacting cells.

Prior Related Work.

- K. Fleisher (SIGGRAPH '95) — Cellular texture generation.
- R. Hoar et al (CEC '03) — Virtual bacteria cultures.
- P. Eggenberger (ECAL '97) — Evolving morphologies ... differential gene expression.

II. Regulatory Gene Model.

Genes. Classified as either **structural** or **regulatory**.

We devote two regulatory genes to each of four structural genes.

Transcription Factors. Associated with concentrations of cellular products. We use four factors/products: **R**ed, **G**reen, **B**lue, and **C**ommunication. The latter factor affects the diffusion of products with neighboring cells.

Activation. When a structural gene is activated it either raises or lowers the concentration of one of the factors. And if the **C** factor is active diffusion occurs.

Calculations. First, based on current cell product concentrations, each regulatory gene R_j is used to determine an activity level r_j . Next, an affinity

$$a = \frac{1}{1 + \exp(\sum_j r_j)}$$

is calculated for the associated structural gene. Finally, the affect of the structural gene is determined by letting

$$\gamma = \begin{cases} -1.0 & \text{if } a < 0.2 \\ +1.0 & \text{if } a > 0.8 \\ 0.0 & \text{otherwise} \end{cases}$$

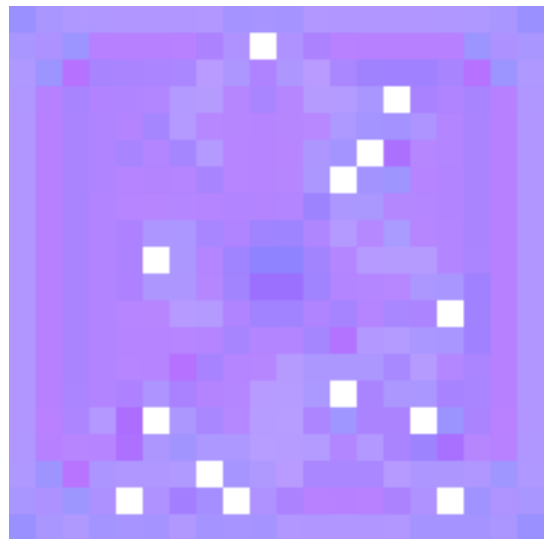
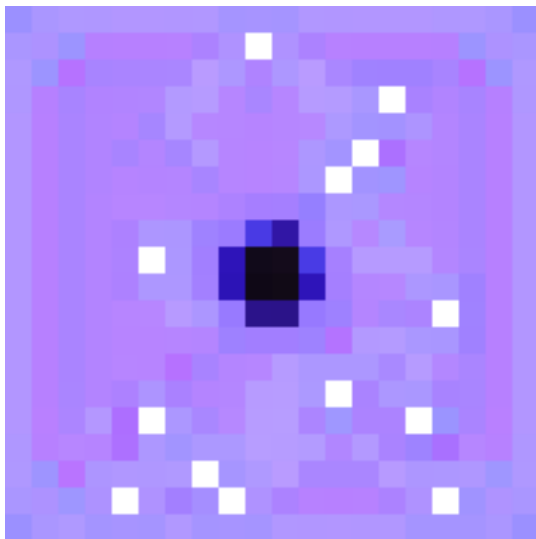
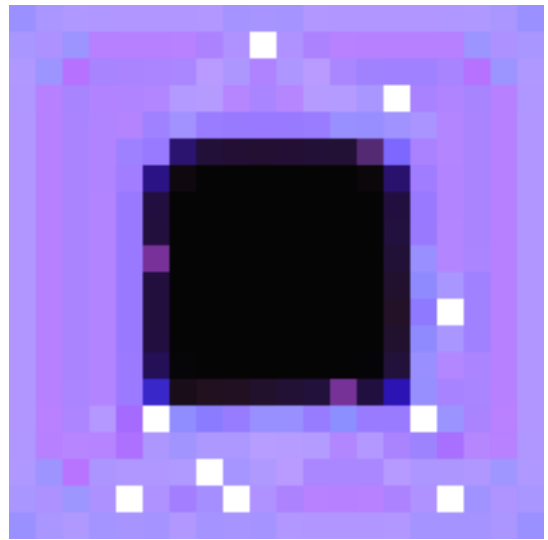
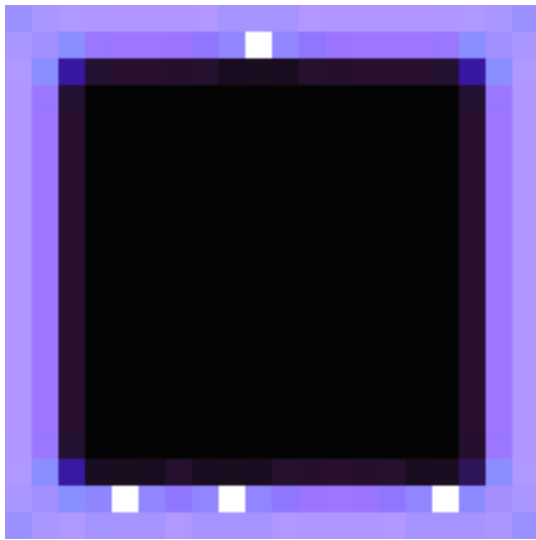
III. Cellular Morphogenesis Simulation.

Substrate. An $N \times N$ array consisting of two types of cells. A fixed **cell pattern** is used during initialization and the ratio between cell types is typically 9::1 or 8::2.

Initial Concentrations. Only **exterior** cells receive initial concentrations of factors.

Length. The substrate undergoes morphogenesis for approximately 350 time steps.

Sample (low res) development sequence:



IV. Automating Aesthetic Evaluation.

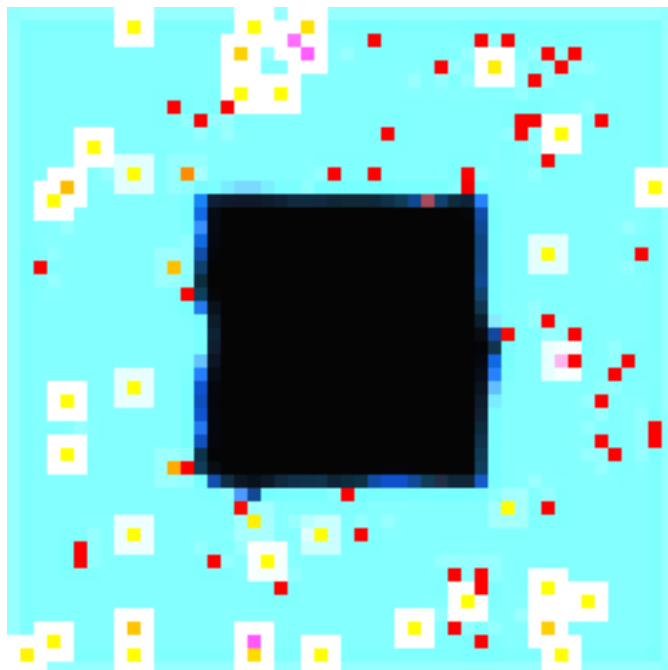
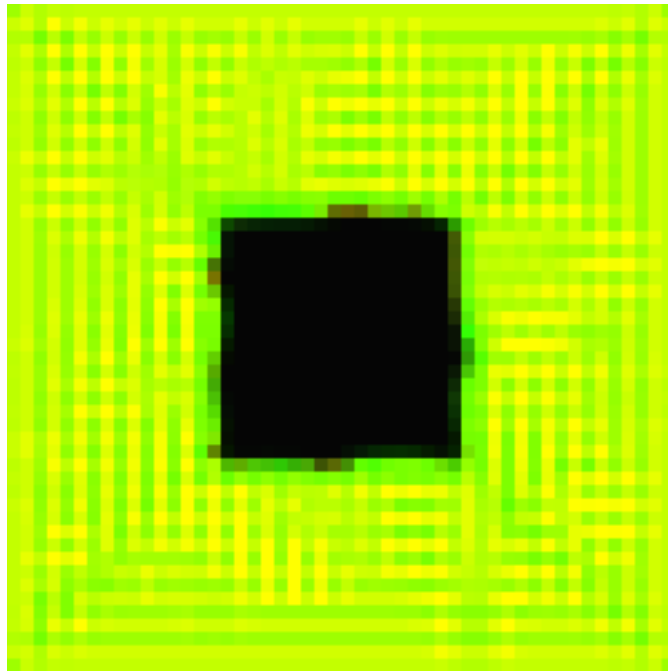
Evolutionary Algorithm Parameters.

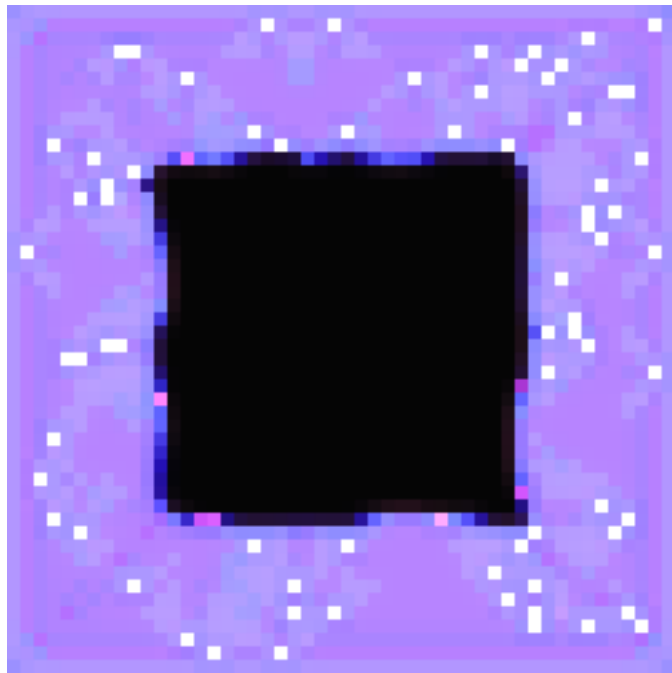
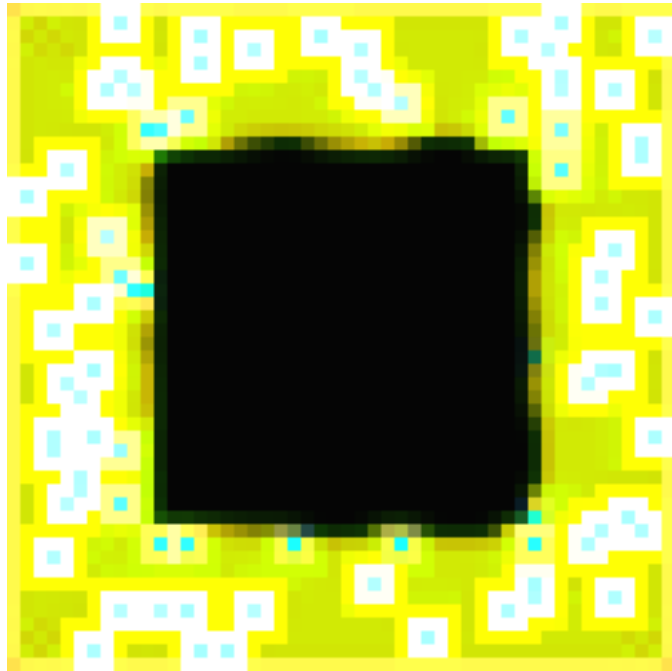
- Population Size: 6–8.
- Number of Generations: 4–8.
- Genetics: One-point crossover, point mutation.
- (Aesthetic) Fitness Calculation:

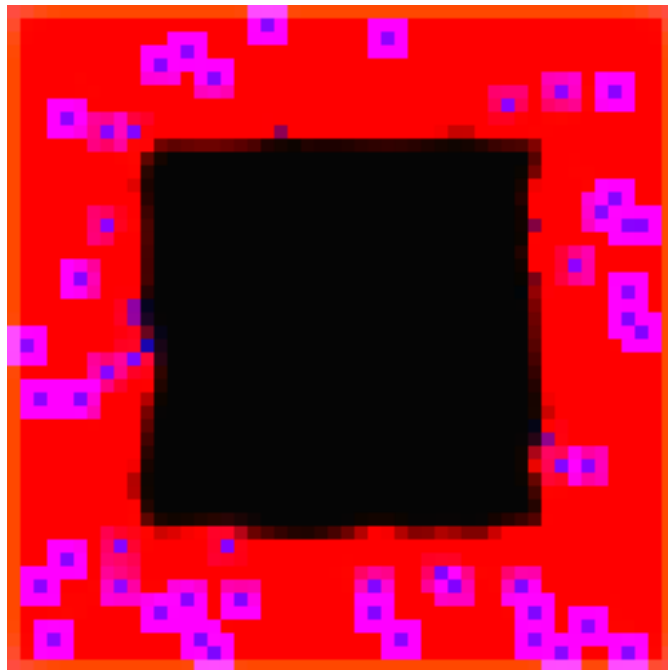
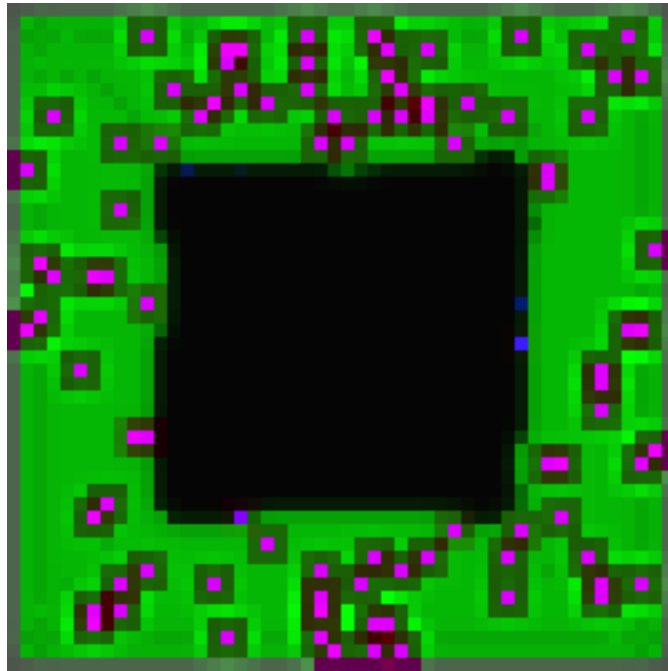
$$\frac{\sigma_C \cdot N_a \cdot \min(\sigma_R, \sigma_G, \sigma_B)}{1 + N_k},$$

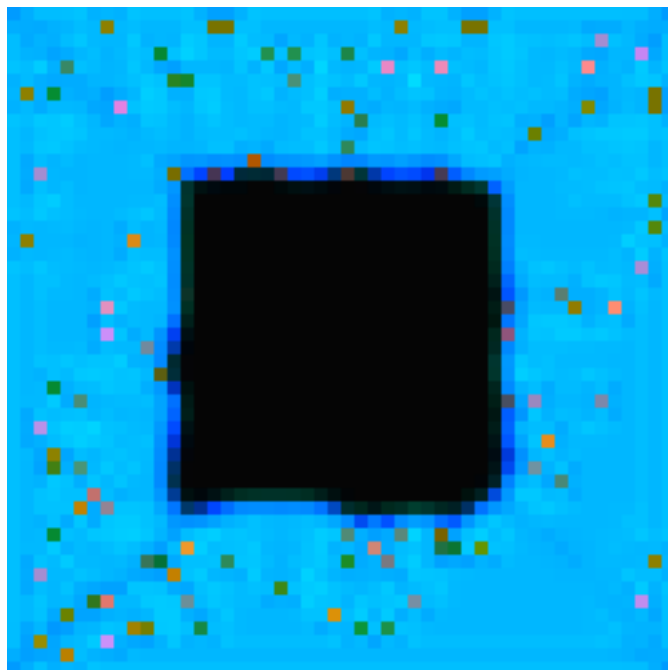
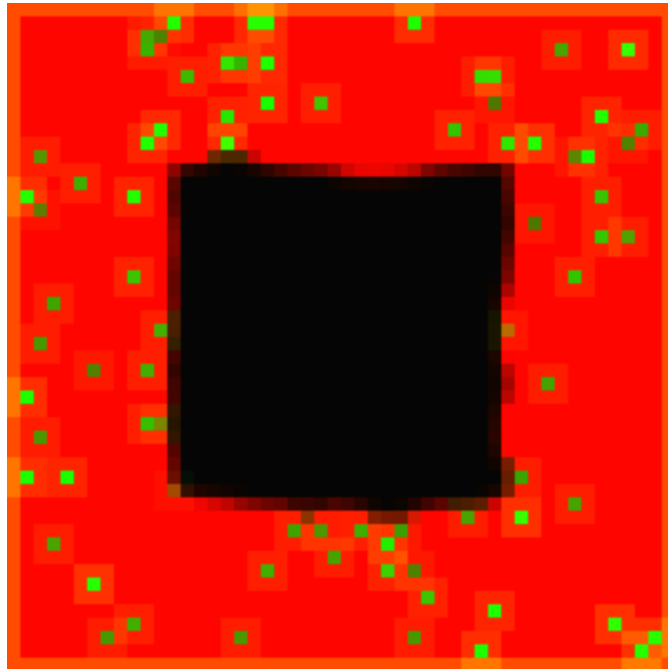
where σ_i is the standard deviation of cell product i concentration; N_a is the number of cells that had a **change** in activation during the preceding time step; and N_k is the number of **dormant** cells.

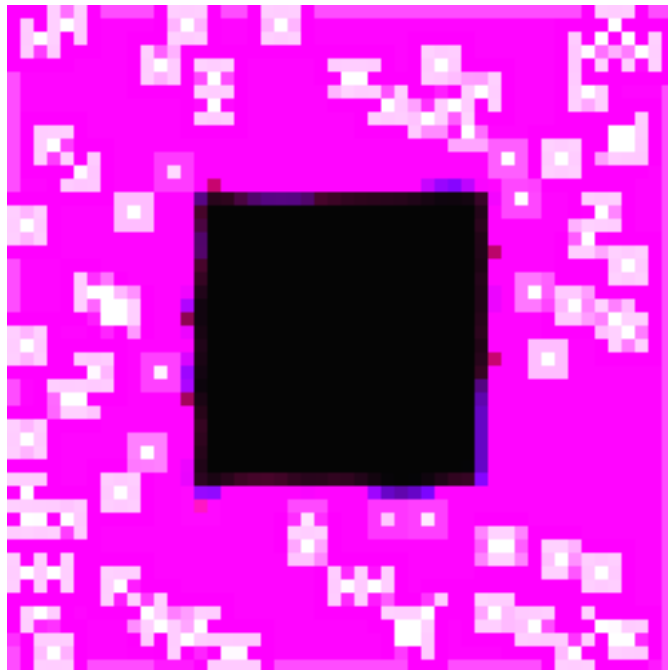
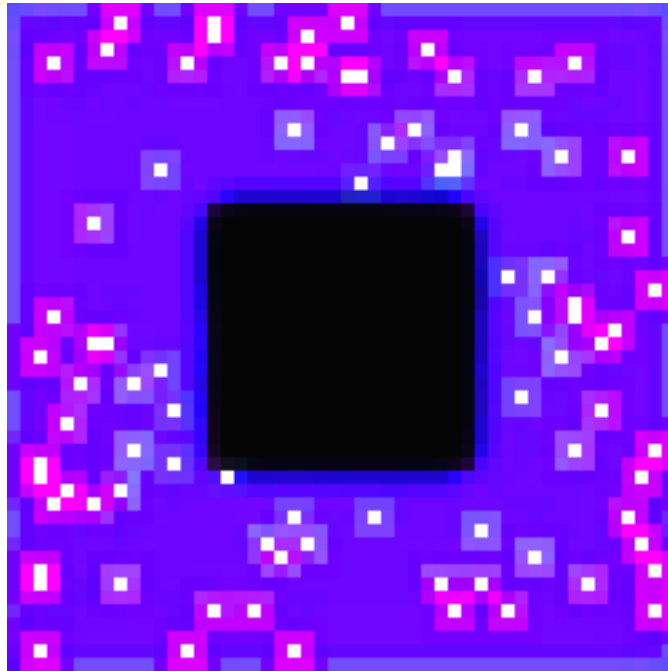
V. The Void Series #0 through #9:











VI. Conclusions and Future Work.

Invite Dialog. About our understanding of cellular processes.

Further Considerations.

- More intuitive regulatory model.
- Other aesthetic measures of fitness.
- Other cell substrate “patterns.”
- Modify genome **during** cellular development.
- Introduce additional transcription factors. *e.g.* aesthetic factors such as opacity or physical factors such as toxins.