Second-Order Cellular Automata as Textile Design Elements

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Abstract

We present initial examples of a body of textile works compositing visualizations of 1D Second-order Cellular Automata with biomorphic elements. The composited imagery is rendered to digital textile prints, and is further enhanced with freehand quilting. These compositions illuminate the naturalistic elements of the cellular automata, as well as the mechanistic elements of the natural forms.

Background

Our previous contributions to Bridges [1] have included photographic elements of natural forms and one-dimensional first-order cellular automata (CA) visualizations [2] incorporated into textile artworks. Given the primary author's interest in incorporating biomorphic forms into her work, we identified examples of second-order CA evolutions that provide convincing mimicry of natural forms. Since this project has at its core the composition of natural forms from photographic imagery, we also included the selection of a limited palette of colors available to the CA imagery. These were drawn from colors present in the photographic imagery to provide digital imagery compatible with the composited photography.

Mathematical Method

Our second-order CA uses elements from two previous generations ($i-1$, $i-2$, see Figure 1) to compute an element (i, j) of the current generation.

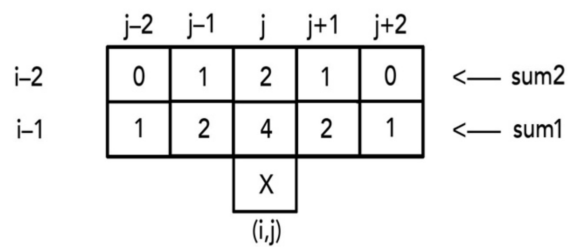


Figure 1: *Our general 2nd-order CA template, showing the elements used to generate X, the (i, j)th element. The numbers shown in generations i – 2 and i - 1 are weights used to scale those elements' contributions to sum1 and sum2.*

In our examples, we have further set the following attributes:

- **Spatial 5-neighborhood:** Only elements with second indices $j-2$, $j-1$, j, $j+1$, and $j+2$ are used to compute an element (i, j).
- **Element 5-valued:** Element values are restricted to integers in $\{0, 1, 2, 3, 4\}$. In visualizations of the CA evolution, these values are mapped to five distinct RGB colors as in Figure 2 below.

These colors were chosen to be harmonious with the photographic imagery selected for the final composition.

- **Totalistic**: A weighted sum of contributions to an element's value is used from generations $i - 1$ and $i - 2$. This sum depends upon contributors' values and positional weights (symmetric left-right).
- **Bounded above**: Since our choice of computation for the CA can result in values outside the range {0, .. , 4}, we arbitrarily set those cell computations to the value 4.

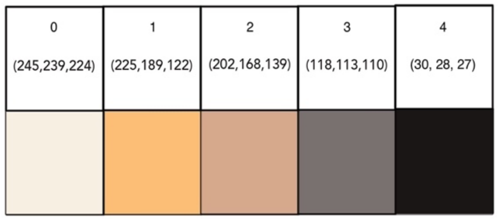


Figure 2: *Color Lookup Table used for mapping element values to RGB pixel colors.*

In choosing the weights applied to each element of the 5-neighborhoods in the previous two generations, a physical heuristic was applied such that elements closer (in both space and time) to an element being computed were weighted more heavily. The rules array was chosen arbitrarily via experimentation to provide both visual interest and a degree of biomimicry when juxtaposed with the photographic imagery selected for the composition. The pseudocode below demonstrates the computation of an element (i, j) using our ruleset and weighted sums over the 5-neighborhoods in the previous two generations. Note that in this example, the rules array and our computation of totSum results in values in the set {0, 2, 3, 4, 5, 6, 7, 8}, which eliminates the color table index 1 color—this shade was determined to be objectionable during experimentation.

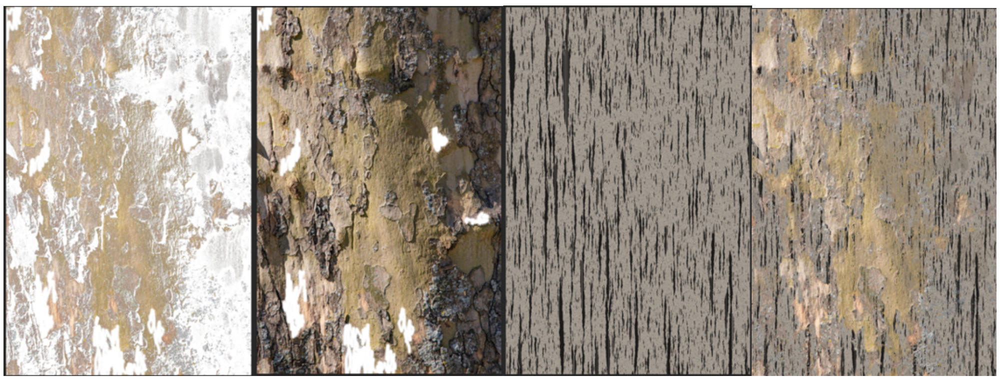
```
rules = [0,3,2,3,0,0,0,4,4]
sum1 = ca[i-1][j - 2] + 2 * ca[i-1][j - 1] + 4 * ca[i-1][j] +
       2 * ca[i-1][j + 1] + ca[i-1][j + 2]
sum2 = ca[i-2][j - 1] + 2 * ca[i-2][j] +
       ca[i-2][j + 1]
totSum = rules[sum1 // 5] + rules[sum2 // 2]
if (totSum < 5):
  ca[i][j] = totSum
else:
  ca[i][j] = 4
```

To generate our CA visualization, we seed the first two generations $i = 0, 1$ with random values in the set {0, 1, 2, 3, 4}, and begin computing new generations at $i = 2$. The Python implementation of our method uses the sys, math, random, svgwrite, and PIL libraries, and we used PIL's PNG output capabilities to render the CA visualization.

Compositing and Quilting

A cropped photographic image of sycamore bark was layered in an image editor on top of a cropped selection chosen from the CA rendering. These cropping decisions were purely aesthetic, rather than rule based. This contrasts with the semi-random CA knitting machine constraints of the Matsumoto, Segerman and Serriere mirror condition of Mobius scarves [3] and the Le Feijs and Toeters Pied-de Poule family of patterns [4].

Each decision in the image composition process is painterly and contingent upon the previous action. A luminosity mask on the sycamore layer allows the underlying CA layer to be revealed where the sycamore layer is in shade. Additional reveals are added to the mask for a better overall balance. With further editing of the transparency mask the juxtaposition of the layers is fine-tuned to make the linear elements cohesive (Figure 3*a*-*d*).



(*a*) (*b*) (*c*) (*d*)

Figure 3: *(a) Luminance mask, (b) Unedited photograph with masked darks, (c) cropped CA output, (d) Final composite.*

The image was digitally printed onto cotton fabric and free-motion quilted on a longarm quilting machine. The dark grey fields of the CA output were quilted with a metallic grey thread and the lighter passages of the sycamore bark were quilted with a gold metallic thread. The final quilted work is shown in Figure 4. Figure 5 shows a related work with second-order CAs composited with Birch bark imagery.

Figure 4: *Second-order CA Sycamore quilt (left) and detail (right).*

Figure 5: *Second-order CA Birches quilt (left) and detail (right).*

Summary and Conclusions

Biomorphic forms are juxtaposed with second-order cellular automaton renderings in five colors sampled from the original photography. Exploration with metallic thread during the quilting process provided another level of quilted depth and contrast with the CA and photographic content. Future work will explore variations in the scale of the CA element size relative to photographic features.

Acknowledgements

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References

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