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Chapter 2
Probabilistic Cellular Automata in the Visual Arts

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In January 1970, computer scientist Leo Geurts walked into Swart Gallery in Amsterdam, The Netherlands, to see the solo exhibition by Dutch artist Peter Struycken (The Netherlands, 1939). He was struck by Struycken's black and white works "Computerstructuren" (1969), which were painted after grid patterns generated by algorithms. Geurts assumed that they must have been produced using cellular automata. He started working with Lambert Meertens at *Mathematisch Centrum* (now CWI) in Amsterdam to make a similar work. This led to what is possibly the first example of the use of probabilistic cellular automata (PCA), entitled *Kristalstructuren* [4, 5, 7]. Struycken did not know both scientists, but "their assumptions about [my] algorithm were too highly fetched. As non-mathematician, I had thought up a much less advanced algorithm for producing my paintings. Their approach made their results more elegant and varied" [18].

The work by Geurts and Meertens was produced using variants of the majority voting rule with asynchronous updating (also related to the Ising spin model (see Chap. 11) and to Potts models (see Chap. 8)). Each lattice site $\mathbf{x}$ had one of two states, $\sigma(\mathbf{x}) \in \{\text{black, white}\}$. The new state was either the majority state (Fig. 2.1c) or the opposite of the majority state (Fig. 2.1d) in the Von Neumann neighborhood $\{\mathbf{x} \pm (1, 0), \mathbf{x} \pm (0, 1)\}$, or, alternatively, in the neighborhood formed by the four diagonal neighbors $\{\mathbf{x} \pm (1, 1), \mathbf{x} \pm (1, -1)\}$. The simulations were initialized with random configurations of $P(\sigma = \text{black}) = 1/2$ and they were updated until the patterns stabilized or entered into oscillation. By means of boundary conditions, the

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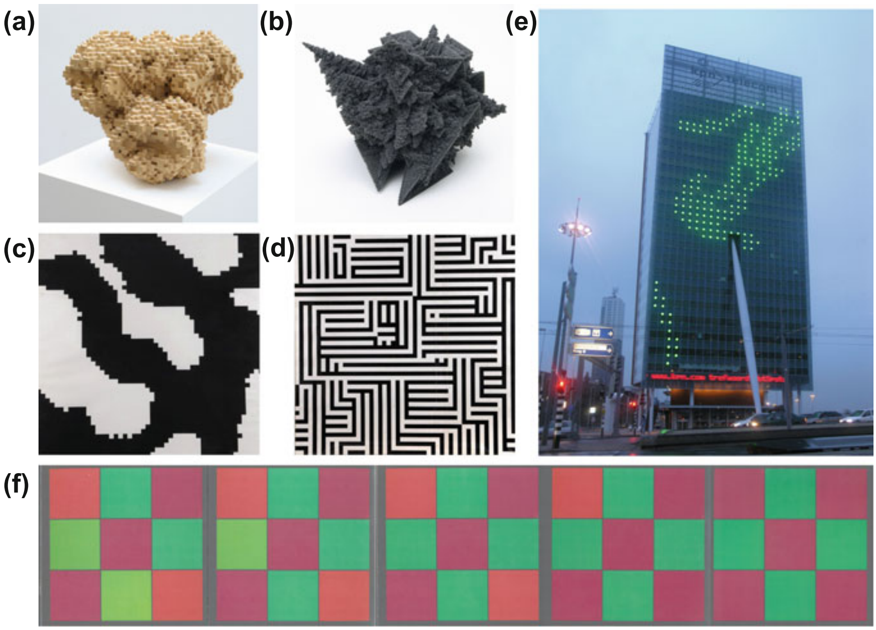

Fig. 2.1 Examples of probabilistic and deterministic cellular automata in the visual arts. **a** *Breed 0.1 #1*, Driessens and Verstappen, 1995; **b** *Accretor #2777-4*, Driessens and Verstappen, 2013, courtesy DAM gallery Berlin; **c,d** *Kristalstructuren* (1970) Geurts and Meertens. **c** Voting rule with Von Neumann neighborhood; **d** opposite of voting rule with Von Neumann neighborhood; Swart Gallery, Amsterdam; **e** *Pixelsex* (2005) courtesy Tim Otto Roth. **f** SPLASH 1972/1974 (1972–1974) Peter Struycken. Stage 24–28 in a series of 28; scan of leporello [16]

boundary rows and columns were initialized randomly like the rest of the lattice and left unchanged during the simulations [5].

Although *Kristalstructuren* found its way into the art market via *Swart Gallery*, this artistic work was a side-branch of Geurts' and Meertens' main line of work in computer science; apart from a few follow-up projects, including a bag for the Dutch mobile supermarket chain "SRV" they concentrated on their scientific work. Struycken's own first use of CA-like algorithms were in his works SPLASH 1972/1974 (Fig. 2.1f) [2, 16, 17]—in which color patterns evolved from an initial pattern towards a preset, final pattern—and later in FIELDS 1979/1980 [14].

Given the attractive patterns that cellular automata can produce [1] and the conceptual interest in the use of algorithms for art, it is perhaps not surprising that other visual artists have also applied cellular automata in their work. Page ix shown an example, entitled *Breed 1.2 #e365* (2007) by the Dutch artist duo Driessens and Verstappen (The Netherlands, 1963, 1964). *Breed* are a series of plywood and 3D printed sculptures (Fig. 2.1a). Not based on PCA in the strict sense of the word, these sculptures were generated by three-dimensional, recursive CA-like rules, generated at random using evolutionary algorithms. To simulate cell division, the 3D lattice was refined after each iteration. Their later series *Accretor* (Fig. 2.1b) are sculptures generated using multi-material 3D printing. Using a three-dimensional accretive growth model [19], similar to a deterministic version of the Eden growth rule [3], randomly selected, deterministic CA-rules determine at which surface positions new particles are added.

In the art project *Pixelsex* by Tim Otto Roth [11] (Germany, 1974), simulations of probabilistic cellular automata were displayed on Renzo Piano's KPN Telecom Tower in Rotterdam in 2005 and 2006 [10]. These PCA have biological application: they are a simulation of the collective behavior of self-propelled myxobacteria ("slime bacteria") [15] using the Cellular Potts model (Chap. 8). Further contemporary professional artists who have used probabilistic cellular automata, include Paul Brown (UK, 1947) and John F. Simon Jr. (USA, 1963); also see Ref. [6, 14].

Despite the attractive patterns they produce, for conceptual reasons many artists are hesitant with respect to the stochasticity of PCA. Driessens and Verstappen deliberately apply deterministic CA-rules, using randomness only for generating initial conditions or sets of deterministic rules. For them the challenge is to 'breed' complex shapes using entirely deterministic rules: "The use of stochasticity in a generative process is a 'trick' that is often used to make the system look more lively" [20]. Tim Otto Roth shares this artistic viewpoint on generative art, contrasting deterministic CA with earlier probability-based art: "I like the contrast that these [deterministic] CA are emergent dynamical systems, but not accidental at all." [12] However, he adds that his "CA based performances with people are in a certain way probabilistic as the actors cannot behave perfectly." [13]

Hopefully this book will help to show that, despite their "accidental" nature, probabilistic cellular automata are more than a 'trick'. In statistical models of natural systems, the probabilistic rules capture the stochastic fluctuations that are a key component of living systems [9] and of many non-living systems [8]. They can drive 'accidental' behavior in some cases, and practically deterministic behavior in others.

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