Playing a 3D Game of Life in an Interactive Virtual Sandbox

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Abstract. We propose a novel artificial-life-oriented media art "RomperSand", which applies a three-dimensional version of the Game of Life (GoL) CA for the construction of an interactive virtual playground. In RomperSand, two distinct sets of state-transition rules are combined together: one for simulating physically plausible motion of virtual sand particles and the other for realizing the GoL-like dynamic behavior of *living* structures. Players can operate several virtual tools to create, destroy, and interact with these structures. The system was implemented as a Windows application and was tested by several users, gaining positive appreciations from them.

1 Introduction

The creation of interactive art has been one of the most effective applications of Artificial Life studies [1,2]. Recently, such interactive art based on cellular automata (CA) dynamics have been proposed [3,4,5]. CA are easy to implement and parallelize, and are capable of generating very complex dynamics; hence they are potentially very useful as a means to generate unexpected complex patterns for media art. Because the influence of a user's interaction on the generated patterns is way too complex to understand or predict, however, it often results in defeating the user's motivation to keep interacting with the CA. This can be a crucial problem when CA are applied to interactive media art.

To address this problem, we assume that introducing an easily understandable, explicit "motif" would help users develop a concrete image of the work in mind and keep their desire to interact with it. Based on this idea, we have developed a novel artificial-life-oriented media art, RomperSand, adopting a sandbox as its motif. In RomperSand, two distinct sets of state-transition rules are combined together: one for simulating physically plausible motion of virtual sand particles and the other for realizing the Game-of-Life (GoL) [6,7] -like dynamic behavior of *living* structures. Players can operate several virtual tools to create, destroy, and interact with these structures.

In what follows, the concept and details of RomperSand are described, with some exemplar screenshots and comments from test players also reported.

M. Capcarrere et al. (Eds.): ECAL 2005, LNAI 3630, pp. 481–490, 2005.

2 System

2.1 Concept

The motif underlying RomperSand is a sandbox. This choice was taken based on the fact that almost all of us share a happy experience in early childhoods to play in a sandbox and enjoy our first interaction with natural/physical materials there. We expected that using a sandbox as the motif of our work would project onto it an easily understandable, familiar image of such joyful experiences with the physical world, thereby helping a user to maintain his/her motivation to keep interacting with complex media art.

RomperSand consists of a three-dimensional virtual arena, in which players can play with virtual sands as they want, using familiar tools such as a rake, a shovel and a water can as an interface.

In this artificial world, water plays a very important role to connect between *living* and *non-living*. Virtual sands are normally dry (i.e., *non-living*) and obey a default state-transition rule for the simulation of physically plausible motion of sands, such as free falls and avalanches. However, players can pour water onto sands using the water can tool. Once the sands become wet, they turn alive, i.e., they begin to behave following a completely different GoL-like state-transition rule. This change often creates unexpected, fancy dynamic structures flourishing out of the spot where water was dropped. In the meantime, the moisture absorbed in sands gradually evaporate. When they become completely dry again, they come back to under the governance by the inorganic virtual physics laws, being gravitated to the ground.

According to the concept described above, all living structures in this world are destined to die eventually because of the inevitable evaporation of moisture. This, however, is expected to motivate players toward continuing interacting with the world, hoping to see life revive and reflourish out of their hands and water cans.

2.2 CA Rules

Technically, RomperSand is a three-dimensional CA lattice space (size: $100 \times 100 \times 20$). Each cube takes one of the five states: *Empty*, *Sand*, *Water*, *Wet Sand*, and *Block* (not mentioned in this paper). In addition, *Water* and *Wet Sand* have an integer value as their internal states (ranging from 0 to 10000 for *Water* and from 0 to 100 for *Wet Sand*), which specifies the amount of water or moisture that the cube contains.

As mentioned in the previous section, RomperSand has two distinct state-transition rule sets. Switching between the two rules are triggered by the addition of water and takes place locally (i.e., there is no global switching). Details of each rule set are described below.

Default Rule. The default rule set works as pseudo-physics laws in this artificial world, where mass (or the total number of sands) is strictly conserved. To achieve such physical plausibility including conservation, this rule is implemented using three-dimensional "Margolus neighborhoods" [8,9], i.e., any $2 \times 2 \times 2$-sized three-dimensional pattern in the space is mapped to another pattern of the same size by this rule. The designed physics laws are summarized as follows: *Sand* and *Water* fall in the air. *Sand* can stack onto other *Sand* cubes, but steep slopes are subject to avalanches. *Water* spreads when it reaches on the ground. More details of the default rule are as follows:

- Vertical falling of sand.
  When a top cube is *Sand* and a bottom cube is *Empty*, the states of top and bottom cubes are exchanged. By this rule, the sand particle falls vertically.
- Avalanche.
  When both the top and bottom cubes are *Sand* but there is an *Empty* cube next to the bottom cube, the top *Sand* is moved diagonally into that empty cube. This rule realizes avalanches of sands slipping down on slopes, potentially capable of simulating sandpile experiments [10] if many *Sand* cubes are dropped at the same location.
- Vertical falling of water.
  This rule is the same as that of *Sand*. When a top cube is *Water* and a bottom cube is *Empty*, the states of top and bottom cubes are exchanged. By this rule, the water drop falls vertically.
- Absorption of moisture.
  When the *Sand* cube comes in contact with a *Water* cube, the *Sand* cube changes its state to *Wet Sand*.
- Diffusion of moisture.
  A *Sand* cube is changed to a *Wet Sand* cube if there is a *Wet Sand* cube in its neighborhoods. This realizes the diffusion of moisture from sand to sand.

Moreover, each cube has a flag that indicates whether it receives an upward force or not. This force is originated from the bottom plane of the 3D lattice space and propagates through sand and water. If this flag is on, the cube does not obey the rule for vertical falling.

- Spread of water.
  A *Water* cube whose flag is on changes the state of its neighbor *Empty* cube to *Water*. This rule is to make water that dropped down to the ground spread over the surface of the ground.

Figure 1 gives a schematic illustration of the default rule described above. Multiple state-transitions may apply in a single neighborhood at the same time if they are not obstructing each other. Figure 2 shows the flowchart of how the default rule determines the behavior of each *Sand*/*Water* particles. There are more technical details in the specific implementation of this rule, especially in terms of how the integer values specifying the amount of water/moisture in *Water*/*Wet Sand* cubes change in diffusion processes. These details are planned to be published elsewhere [11].

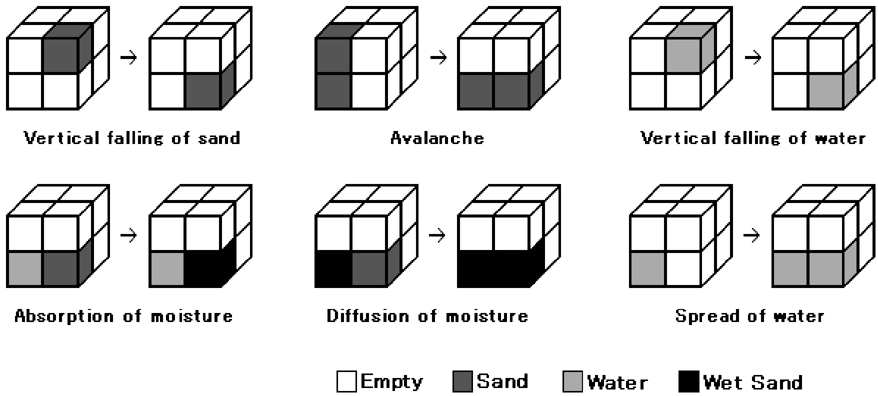

Fig. 1. Schematic illustration of the default rule

GoL-like Rule. When *Water* and *Sand* come to contact, the *Sand* cube becomes *Wet Sand* (i.e., *living*). Then, on this cube and its surroundings, the other GoL-like rule starts to apply, and lasts until they become completely dry again.

The size of its neighborhood template is 27 ($3 \times 3 \times 3$) with this rule. A new *Wet Sand* cube will appear if the total number of living cubes in the surrounding neighborhoods is either 4 or 5. A living cube will die if the number is not exactly 5. When cube changes from living to non-living, its state will be cleared to *Empty*. In our implementation, however, we heuristically set the probability of this type of state-transitions to be 1/2, in order to make the generated behavior more interesting.

2.3 Implementation

RomperSand was implemented as an application software that runs on a Windows (2000 or XP) based PC. It was written in C++ using Direct X. It can be downloaded from the authors' website[1].

Figure 3 shows a sample screenshot of RomperSand. A rake, a water can, and a shovel are displayed as icons at the upper left corner of the window. Players can select which tool to use by clicking on these icons. The rake can be used to collect sands. The water can is used to sprinkle water. The shovel can be used to dig up and scatter sands. Figure 4 shows exemplar scenes of the use of these virtual tools.

3 Characteristic Dynamics

RomperSand has been demonstrated internally in our facility, where more than 10 test players enjoyed playing with this artwork (Fig. 5). The players reported

[1] http://cx.hc.uec.ac.jp:8100/~ogihara/

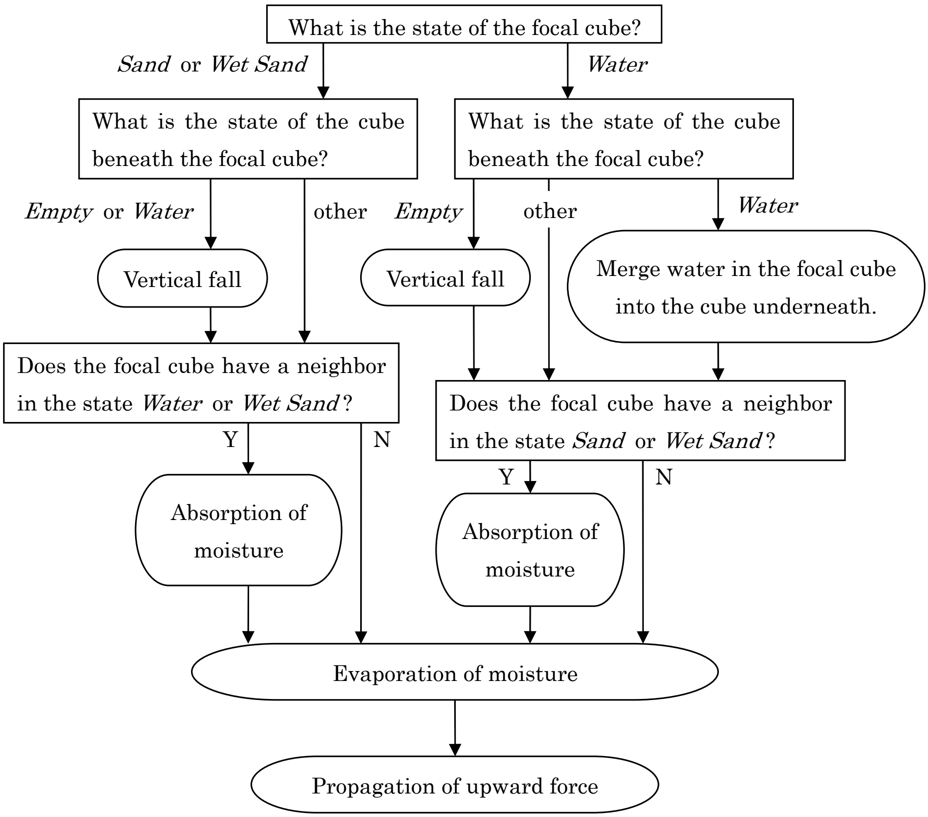

Fig. 2. Flowchart of the default rule

that there are at least three salient dynamic structures made of living sands that are easily identifiable in this world.

- Fountain of sands.
  A pattern in which sands come out one after another from the ground. This looks like a fountain of sands (Fig. 6).
- Elevating sands.
  A pattern of rising *Wet Sand* cubes. This pattern eventually ends up by scattering dried *Sand* cubes falling back to the ground, whose appearance is really dramatic (Fig. 7). This is considered similar to gliders in the original GoL.
- Crawling sands.
  A pattern that crawls toward one direction on the surface of the ground (Fig. 8). This is another kind of glider-like structure in this world. This is often mistakenly understood by the players as if there were some sort of living thing like a mole in action.

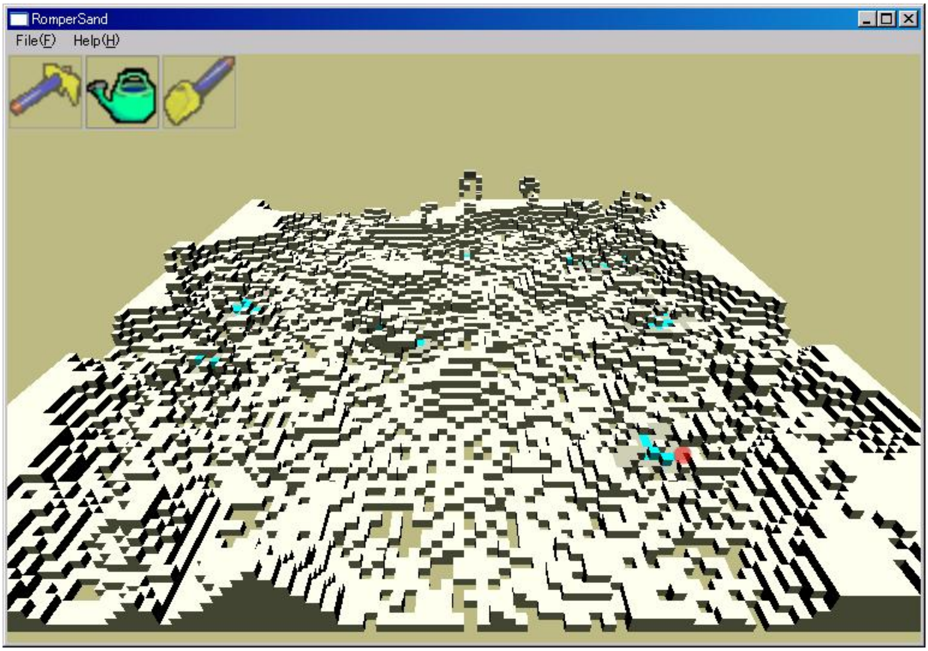

Fig. 3. A screenshot of RomperSand

Comments for RomperSand given by the test players are summarized below:

– "It is interesting that sand collapses when water is poured."
– "I think it is quite new that sands do irregular movements and splash sometimes."
– "The movement of sand is so drastic when I add water, so it is difficult to predict what I am going to make. But, because the collapsing scene was interesting, it is not frustrating."
– "This is very interesting to see as it moves by itself."

The duration of free play with RomperSand by the test players ranged from a couple of minutes to more than half an hour, about five minutes on average. All the test players appreciated the concept of this artwork and agreed with our intention to use a sandbox as its motif to promote users' motivation to interact with media art, suggesting that our original goal was achieved in this work to some extent.

4 Conclusion

We have presented an interactive artwork, named RomperSand, which includes as part of its dynamics a 3D version of the Game of Life. It aims to introduce a concrete motif of "sandbox" to CA-based media art that would otherwise be

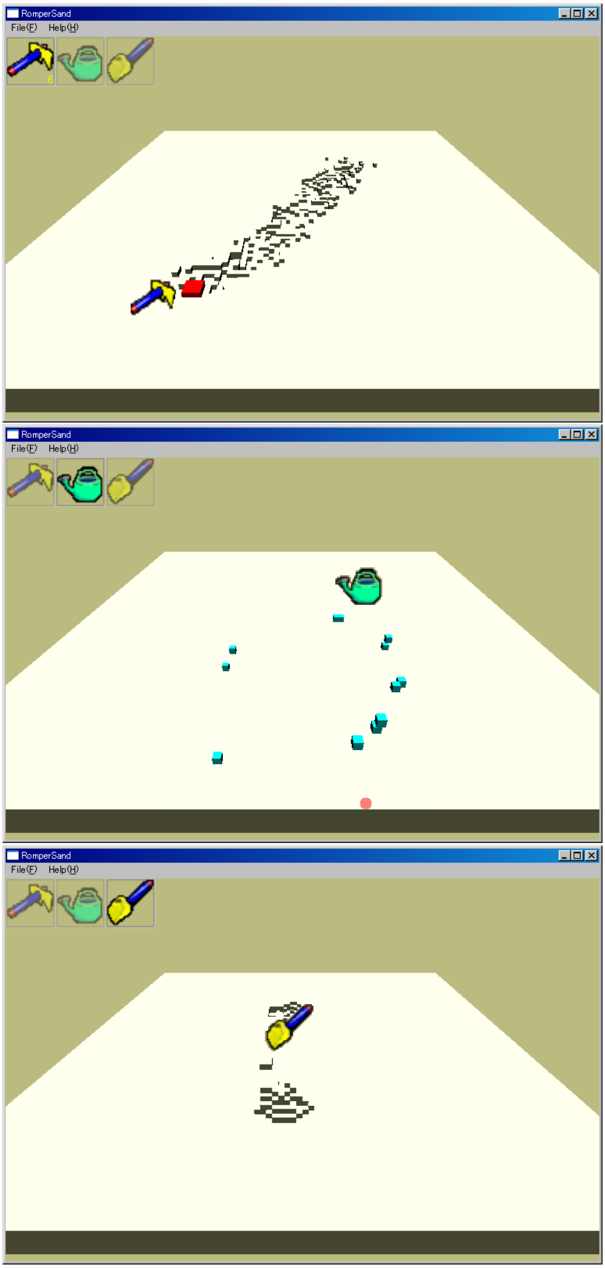

Fig. 4. Virtual tools in use (top: rake, middle: water can, bottom: shovel)

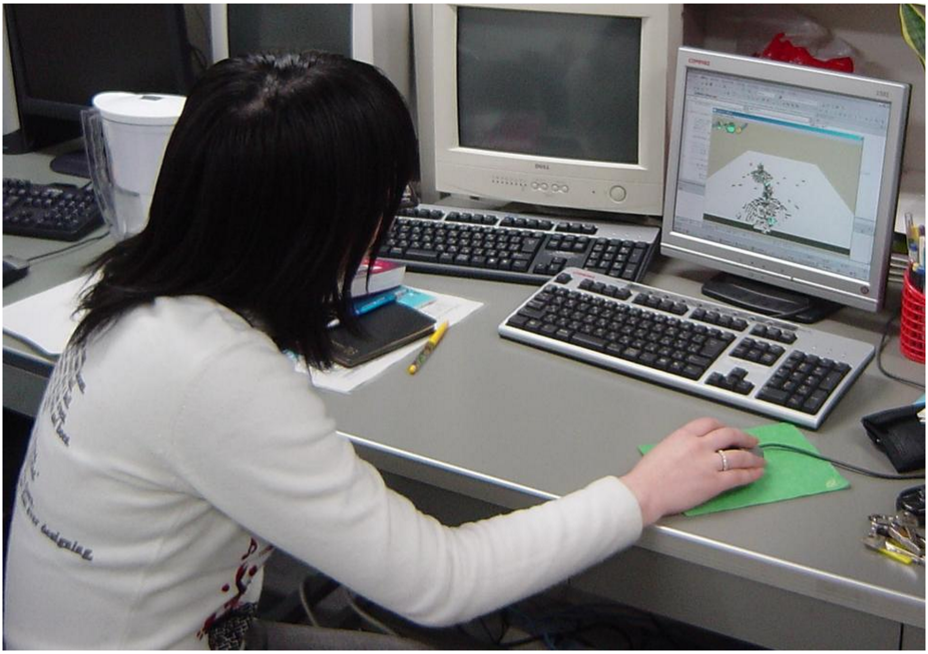

Fig. 5. A player playing with RomperSand

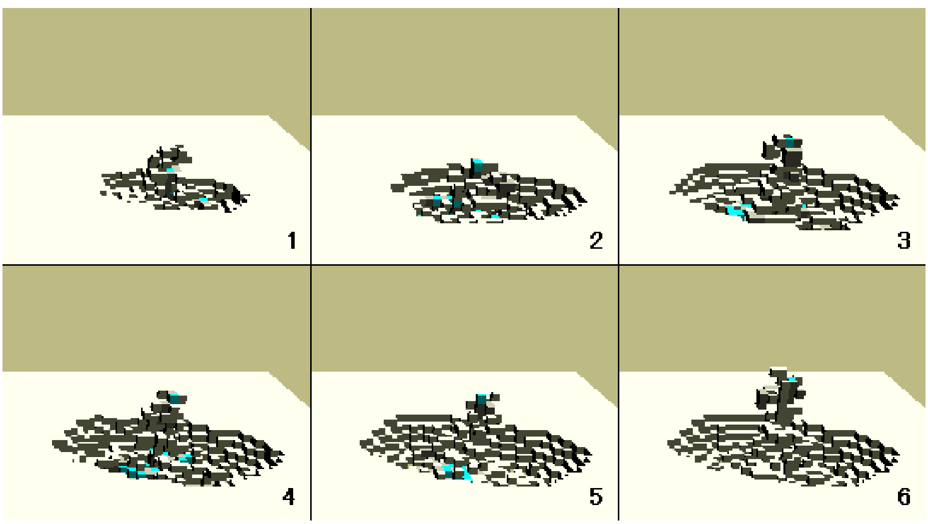

Fig. 6. Fountain of sands

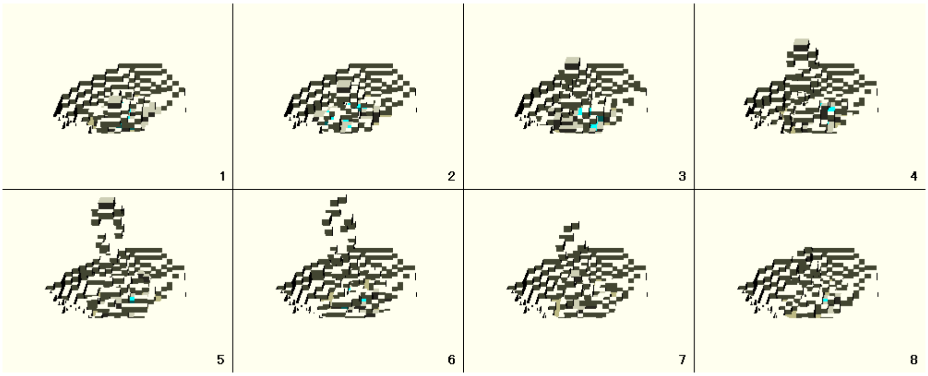

Fig. 7. Elevating sands

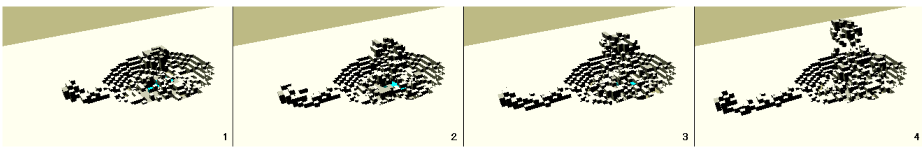

Fig. 8. Crawling sands

too complex to maintain the users' motivation for interaction. The combination of two distinct rules (the default pseudo-physics rule and the 3D GoL-like rule) was done by placing water onto the intersection between these two *non-living* and *living* regimes. Our attempt seems successful in view of positive reactions and appreciations received from the test players who played it.

RomperSand is still under major revision and development. Further improvement would be definitely needed, firstly for expansion of space (or increase of resolution of space) and secondly for increasing the speed of the CA simulation and response to the use of virtual tools. These would be crucial in improving the interactivity of RomperSand. A systematic analysis of the model's basic dynamics from technical/theoretical viewpoints would be another important direction of future work.

References

1. Sommerer, C. and Mignonneau, L.: Modeling emergence of complexity: The application of complex system and origin of life theory to interactive art on the Internet. In Artificial Life VII: Proceedings of the Seventh International Conference on Artificial Life, Bedau, M. A., McCaskill, J. S., Packard, N. H. and Rasmussen, S., eds., Cambridge, MA: MIT Press, 2000, pp. 547-554.
2. Mignonneau, L. and Sommerer, C.: Creating artificial life for interactive art and entertainment. In Artificial Life VII: Workshop Proceedings, Maley, C. C. and Boudreau, E., eds., 2000, pp. 149-153.

3. Dorin, A.: LiquiPrism: Generating polyrhythms with cellular automata. In Proceedings of the 2002 International Conference on Auditory Display, Nakatsu, R. and Kawahara, H., eds., Advanced Telecommunications Research International (ATR), Kyoto, Japan, 2002, pp. 447-451.
4. Tempesti, G. and Teuscher, C.: Biology goes digital: An array of 5,700 Spartan FPGAs brings the BioWall to “life”. XCell Journal, Fall 2003, pp. 40-45.
5. Kodama, S., Fukuda, Y., Sayama, H. and Koike, Y.: Living Surfaces - A concept of animated texture using “Evoloop” and experiments in an interactive art. Journal of the Society for Art and Science 3: 193-196, 2004. Witten in Japanese.
6. Berlekamp, E., Conway, J. H. and Guy, R.: Winning Ways, vol 2, New York: Academic Press, 1982.
7. PoundStone, W.: The Recursive Universe. New York: William Morrow and Company, 1985.
8. Toffoli, T. and Margolus, N.: Cellular Automata Machines, Cambridge, MA: MIT Press, 1987.
9. Margolus, N.: Physics-like models of computation. Physica D 10: 81-95, 1984.
10. Bak, P., Chao, T. and Kurth, W.: Self-organized criticality. Phys. Rev. A 38: 364-374, 1988.
11. Ogihara, D. and Sayama, H.: In preparation.