A Generation Method of Rust Aging Texture Considering Rust Spreading

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***Abstract*— Rust is indispensable in order to synthesize realistic computer generated images. There are two kinds of rust. One is a kind of rust that iron was corroded actually, and another is a kind of rust that has been peeled from rusted iron surfaces and drifted flow of rainwater. We have developed a rust simulation system based on a cellular automaton that generates rust aging textures considering two kinds of rust. Several simulation results verify that two kinds of rust is effective to generate rust aging textures compared with real rust photos.**

Keywords—component;Computer Graphics, Rust simulation, Main-rust, Sub-rust, Cellular automaton

I. INTRODUCTION

In recent years, 3D computer graphics (3DCG) techniques are developed, and it is possible to create realistic 3DCG images. However, most of the objects that exist in real world have scratches or dirt. In order to generate a realistic 3DCG model, depicting deterioration, dirt, and damage is important. In this paper, we propose a method that generate rusts automatically caused by a deterioration of iron plate.

Yao-Xun Chang et al. [1] is simulated growing progress of rusts in a sea by L-system. Kamata et al. [2] also proposed a growing simulation of rust by L-system. However, L-system is a complex, and it is difficult to control. Doi et al. [1] proposed a method to generate automatically a rusts texture using two-dimensional cellular automata. This method is called two-dimensional cellular automata for growing rusts progress in this paper. However, their approach does not take into account the slope of an iron plate. Therefore, there method only can represent rusts occurring on a horizontal iron plate.

We extend the two-dimensional cellular automata for growing rusts progress, and propose a method that generate rust texture considering the tilt of iron plate. In addition, we divide rusts into two the following. First is iron corrosion (called main-rust). Second is flowing down main-rust by rain (called sub-rust). We propose a method that focus on these two type rusts. Therefore our method can generate realistic rusts.

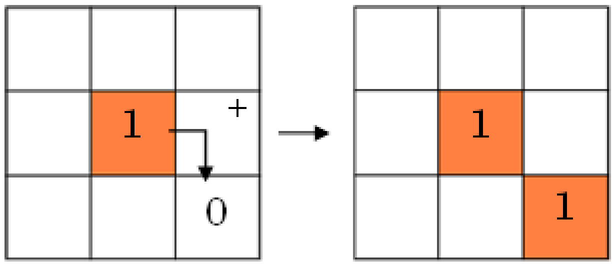
II. THE PREVIOUS STUDIES BY TWO-DIMENSIONAL CELLULAR AUTOMATE

In this chapter, we describe a Doi et al method [3] that we used as a reference.They simulate a growing progress of rusts by using a two-dimensional cellular automata of 256 × 256 cells. Each cell has 5 parameters, vertex coordinates, surface attributes, growth level, phase level, and rust occurrence probability.

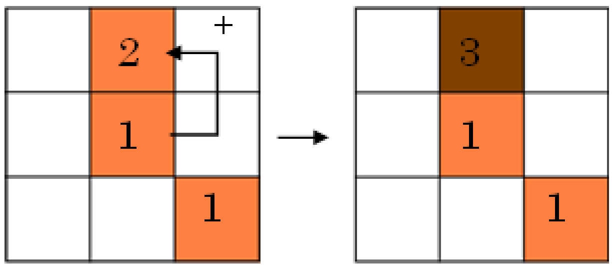
Vertex coordinates store position information(x, y coordinates) of the cell. Surface attributes store value of environment light component, diffuse reflection component and specular reflection component. Growth level is a numerical value indicating the growing progress of rusts in each cell and used to expand the rusts. Phase levels is a parameter to determine color of rusts by growth levels. Rust occurrence probability is a parameter for controlling a probability of rusts occurs.

Our method expand rusts by raster scanning entire cell. Rusts grow by propagating growth level of a cell to the neighboring cells. As shown in Fig. 1 (a), when the growth level is 1 or more, we randomly select one cell from the eight neighboring cells. Next, the growth level of the selected cell is incremented. When growth level of the cell reaches a predetermined value or more, phase level of the cell is incremented. The cell color changes darker (Fig. 1 (b)) by incrementing phase level. Rust is grow by previous described procedure. In other words, iron plate corrosion advance.

A method by cellular automata of Doi et al., simulates growing progress of real rusts with a simple algorithm. However, this method can only represent rusts occurring on a horizontal iron plate. Thus, inclination of an iron plate does not affect rust shape or occurrence position in this method.



(a) When growth level is 1 or more, we randomly select one cell from eight neighboring cells. Growth level of the selected cell is incremented.



(b) When growth level reaches a predetermined value or more, phase level is incremented and rust grow.

Figure.1 Growth control of rust by cellular automata

III. IMPLEMENTATION

Our proposed method based on the two-dimensional cellular automata for rust progress of Doi et al., allows generation of rust texture considering slope of an iron plate. And our method improved based method by dividing rusts in main-rust and sub-rust.

A. Description of main-rust and sub-rust

Main-rust is portion of corroded iron plate. On the other hand, sub-rust are main-rust that peeled off by wind and rain. Sub-rust move to direction of gravity by mixing with water drops. Sub-rust apparent have a rust-colored. Since Sub-rust is not actually corroded to generate rust, and easily flows out dissolved in rain. However, the sub-rust occurs, there is moisture and impurities tends to remain. When the moisture remains on the surface, wetting time[4] is longer. This means that main-rust is likely to occur. We improve the method of Doi et al. To be able to simulate the behavior of these main-rust and sub-rust.

B. Structure of the cell

The following are the details of the parameters. In order to simulate the growth of main-rusts and sub-rusts, we divide the growth level of each cell into main-rust growth level and sub-rust growth level. Accordingly, each cell has 6 parameters, vertex coordinates, surface attributes, main-rust growth level, sub-rust growth level, phase level, and rust occurrence probability.

(1) Vertex coordinates: This parameter stores position information(x, y coordinates) of the cell.
(2) Surface attributes: This parameter stores a value environment light component, a diffuse reflection component and a specular reflection component.
(3) Main-rust growth level: This parameter indicates the growing progress of a main-rust of each cell.
(4) Sub-rust growth level: This parameter indicates a growing progress of the sub-rust of each cell.
(5) Phase level: This parameter determines color of main-rust and sub-rust by rust growth levels.
(6) Rust occurrence probability: This parameter is a probability that main-rust occurs.

C. Behaviors of main-rust

We scan all cells of a two-dimensional cellular automata by raster scan. If rust occurrence probability of a cell is threshold or more, main-rust growth level of the cell is incremented. We set rust occurrence probability to 0.001%.

While we repeat raster scan of all cells, main-rust is grown by two steps described below.

(1) If main-rust growth level of a cell C(x, y) is more than 1, one cell is selected from cell C(x±1, y±1), C(x±2, y) and C(x, y±2) at random (Fig. 2). Main-rust growth level of the selected cell is incremented. We call the selected cell as C(x', y').
(2) In order to simulate a rust growing progress taking an inclination of the surface in to account, we propagate rusts generated in step (1) in a direction of gravity. That is, we determine a propagation range αx, αy in the direction of gravity (Fig. 3 (a)). Then, we increment main-rust growth level of entire cell between C (x', y') and C ($x' + \alpha x$, $y' + \alpha y$). We determine αx and αy by the following formula.

$$\alpha x = \begin{cases} 0 \ldots Horizontal\ plane \\ 0 \ldots 45° inclined\ plane \\ -1 \sim 1 \ldots Vertical\ plane \end{cases}$$

$$\alpha y = \begin{cases} 0 \ldots Horizontal\ plane \\ 0 \sim 1 \ldots 45° inclined\ plane \\ 0 \sim 2 \ldots Vertical\ plane \end{cases}$$

Main-rust repeats expanding and generation by these processes. If rusts propagate to x-axis, we reduce propagation to y-axis direction. Thus rust shapes in our proposed method become a similar shape of rust in real world.

D. Behaviors of sub-rust

Sub-rust is a rust that occurs from main-rust. Occurring and growing algorithm of sub-rust is described as following.

(1) Sub-rust is generated from a cell that main-rust growth level or sub-rust growth level is 1 or higher. If main-rust or sub-rust growth level of the cell C (x, y) is 1 or more, one cell is selected from cell C(x±1, y±1), C(x±2, y), and C(x, y±2) at random.
(2) Sub-rust grows taking inclination of an iron plate into account too. Similarly main-rust, we also propagate a sub-rust that was expanded and propagated by step(1) in a direction of gravity. We determine a propagation range βx and βy in a direction of gravity (Fig. 3 (b)). And we increment a sub-rust growth level of entire cell between C (x'', y'') and C ($x'' + \beta x$, $y'' + \beta y$). We determine βx and βy by the following formula.

$$\beta x = \begin{cases} 0 \ldots Horizontal\ plane \\ 0 \ldots 45° inclined\ plane \\ -1 \sim 1 \ldots Vertical\ plane \end{cases}$$

$$\beta y = \begin{cases} 0 \ldots Horizontal\ plane \\ 0 \sim 3 \ldots 45° inclined\ plane \\ 0 \sim 6 \ldots Vertical\ plane \end{cases}$$

(3) If sub-rusts occur on an iron plate, moisture and impurities easily remain in the spot. Because wetting time in the spot is longer, main-rusts easily occur. Therefore, a cell that sub-rust occurred occur easily when raster scan of all cells by increasing rust occurrence probability. Rust occurrence probability of the cell set to 0.01% experimentally.

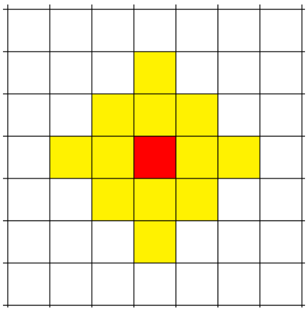
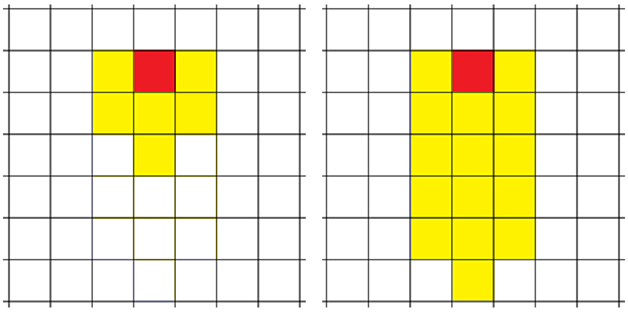


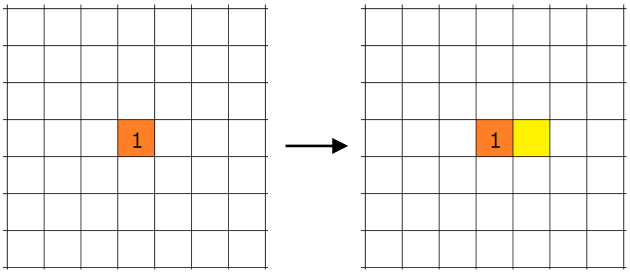
Figure.2 Expanding range of rust



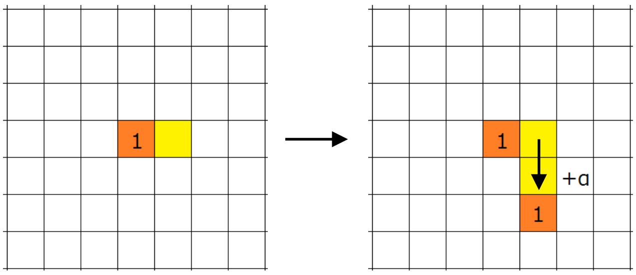
(a)Propagation range of main-rust to the gravity direction α (b) Propagation range of sub-rust to the gravity direction β

Figure.3 Propagation range of the gravity direction

We show a flow of main-rust expansion and propagation to gravity direction in Figure 4.



(a) If main-rust growth level of cell C (*x*, *y*) is 1 or more, one cell is selected from cell C(*x*±1, *y*±1), C(*x*±2, *y*), and C(*x*, *y*±2) at random.



(b) Next, we determine the propagation range αx and αy in the direction of gravity. Then, the cell C (x', y') to the C (x' + αx, y' + αy), we will increment main-rust growth level of the cell.

Figure.4 Propagation and expansion of rust to gravity direction

E. Rusts color

We perform main-rust and sub-rust growing process of above-mentioned at raster scanning of all cells. Thereafter, we determine a color of rust in accordance with a growth level of the main-rust and sub-rust of each cell. We set a color of rust in each cell and outputs these colors as an image. Table 1 shows relationships between growth levels and colors of main-rust and sub-rust. These relationships are determined by iron plate exposure experiment results [4].

Table 1 relationship between each growth level and color

Color	Main-rust	Sub-rust
Iron plate color	-	0
Pale yellow	-	20
Pale brown	-	40
Ocher	-	70
Brown	5	-
Umber	25	-
Black brown	40	-

IV. IMAGE GENERATION RESULTS

We generated a rust texture by tour proposed method considering the main-rust and sub-rust.

A. Rust of progress simulation results

Figure 5 shows a simulation result of growing progress of rust by a process described in the previous section. Figure 5 (a) shows a simulation results considering main-rust and sub-rust by our proposed method. Figure 5 (b) shows a result of a conventional method considering only main-rust.

Our method improve reality of rusts. And our proposed method show that rusts advance and droop gradually to direction of gravity with growing progress of rusts.

B. Comparison of the actual rust

We generated rusts texture from a relationship between the growth level and color of main-rust and sub-rust shown in table 1. The result is shown in Figure 6 (b). We compared real rusts photo (Fig. 6 (c)) with our results (Fig.6 (b)). It can be seen that very similar results were obtained.

V. CONCLUSION

We propose a method to generate rusts texture taking main-rust and sub-rust into account. Our method can generate more realistic rusts texture than conventional methods.

In the future, in order to obtain more detail rusts texture, we think enlarging a resolution of two-dimensional cellular automata. In addition, we think that our method improve to be able to apply various angles and shapes.

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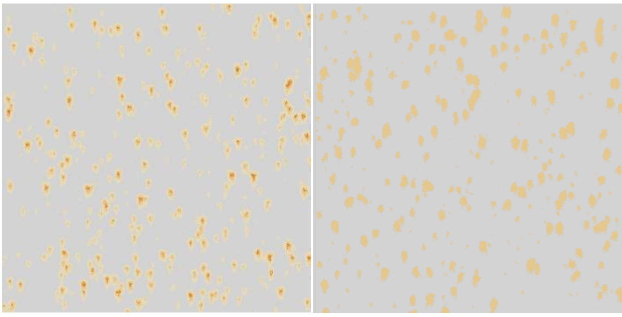
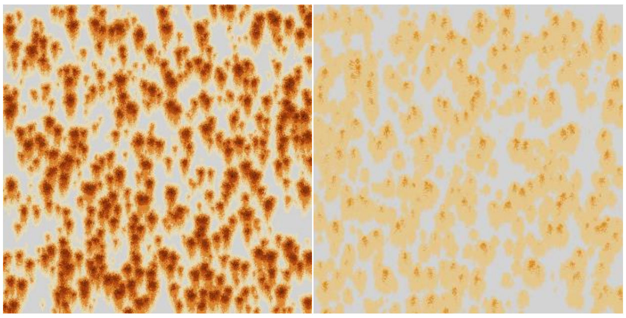
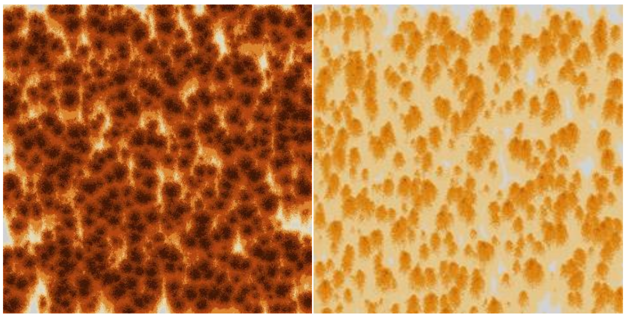
Time of step 1



Time of step 15 (Main-rust/Sub-rust)　Time of step 15 (Main-rust only)



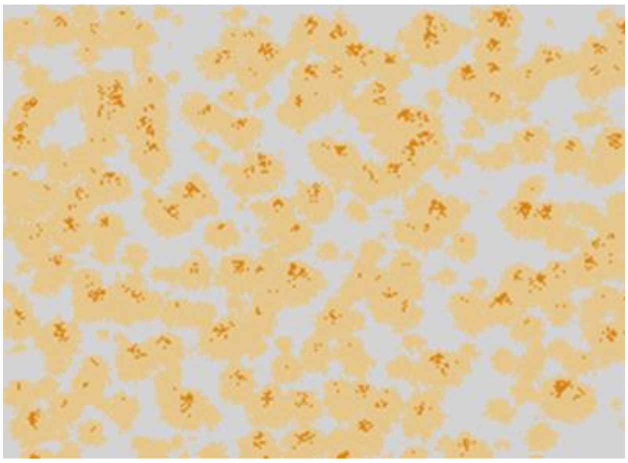
Time of step 30 (Main-rust/Sub-rust)　Time of step 30 (Main-rust only)



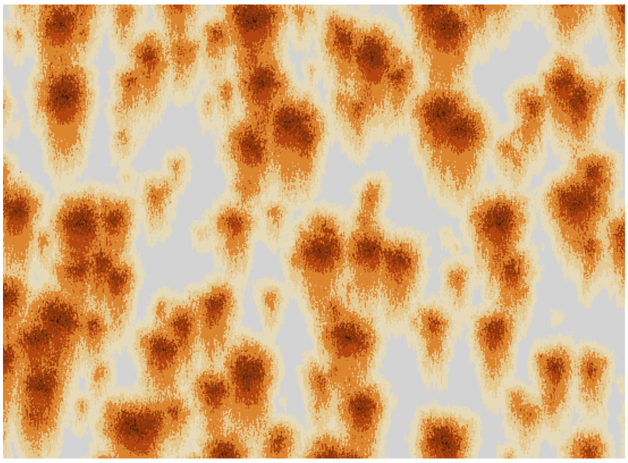
Time of step 45 (Main-rust/Sub-rust)　Time of step 45 (Main-rust only)

(a) Main-rust and Sub-rust　(b) Main-rust only

Figure.5 Simulation result



(a) Main-rust only



(b) Main-rust and Sub-rust

(c) Real rusts photo

Figure.6 Comparison of the simulation results and a real rusts photo