A Study of Generating Weathered Patterns by Using Fractal Functions

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EXTENDED ABSTRACT

Computer Graphics technology has developed very rapidly and is used in many fields such as industrial design, architecture, scientific simulations, movies, entertainment and so forth. It has also created another technology called *Virtual Reality*, which generates a virtual space where the same environment as the real world exists. Human can share the same sense as the real one such as vision, hearing, touch, smell and taste. By using virtual reality technology, the same city as the real one could be created in a virtual space and many simulations become available. For instance, a new building can be evaluated if it matches in the environment before the building is built or people can feel the atmosphere of a city where they have never been. In this case, many objects such as buildings, roads, bridges and so on should be built manually with computer graphics modeling software. It requires huge work especially for giving the size and color of the objects. For the size problem, there are some methods which build objects based on 2 dimensional maps and stereo images taken from an airplane. On the other hand, *Texture Mapping*, is used to solve the color problem. Texture mapping is one of computer graphics technologies that maps real pictures onto surfaces of models created by computer graphics software. This technique can make objects in a virtual space very realistic. However, taking good pictures for texture mapping requires a lot of work, because good pictures should be taken at the front of the objects, should have no distortion, should have good luminance. Moreover, they should for display, should be changed very easily in luminance according to display time, and should be changed by the environment and day by day.

Therefore, there are some researches that generate weathered images by adding some stains such as rust, water drop, foot-print and so on. These techniques can change texture mapping images according to the environment and day by day. Moreover, these take huge time to generate the pictures and these purposes are not general, and also cannot be used for weathered walls or roads, which appear very often in landscape simulations.

This paper describes a method which can generate weathered textures used in landscape simulations by using *Fractal Functions*. The purpose is to generate weathered images of walls or roads, which have two types of features to represent themselves realistically. One is the shape of the surface of walls or roads and the other is weathered patterns of them. In computer graphics, *Bump Mapping* can be used to change the surface shape of objects; however, it takes much time to render the image because it has to perform illumination calculation by using normal vectors that is given and changed by users. Then, this research proposes to generate uneven surfaces by using black and white pixel patterns called *Pixel Pattern*. The generated uneven surface is called *Material Image* in this paper. On the other hand, weathered patterns are generated by fractal functions, which are often used to represent natural images. Fractal functions generate images by representing the same shrunk pattern recursively. In this recursive procedure, another image can be generated by rotating the pattern. By composing some images generated with fractal functions, *Fractal Image* can be generated. Finally, *weathered Image* used in landscape simulations can be generated by composing material image and fractal image. Figure 1 shows the procedure of this paper.

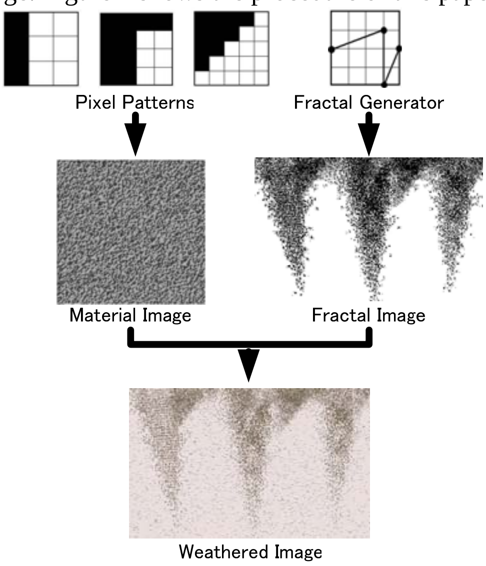

Figure 1. A generation method of weathered images

1. INTRODUCTION

Computer Graphics technology has developed rapidly and is now used in many fields such as industrial design, architecture, movies, entertainments and so on. One of the applications is landscape simulation that can evaluate if a new building matches the environment before the construction. In this case, real pictures are mapped onto the surfaces of the objects, which are manually created with computer graphics modeling software. There are several types of weathered images so that some researches are investigated, which automatically generate manmade stains such as water drops, foot-print and so on. These simulations can generate real images, while they take much time to generate the images and the generated images are specific and not general for multi-purpose. Therefore, this paper describes a generation method of weathered images generally used for landscape simulations. The purpose of the research is to generate images of walls or roads that have stains and often appear in landscape simulations. The image is composed of two types of images: material image and fractal image. Material images can be generated by placing black and white pixel patterns at random, while fractal images can be generated by fractal functions. Finally, weathered images used in landscape simulations are generated by combining them.

2. RELATED WORKS

There are some researches that automatically generate realistic images by computer graphics. Weathered images caused by water flow could be made with a model where each water drop is a particle (Dorsey *et al*. 1996a) and Metallic patinas was simulated with a collection of operators such as coat, erode and polish. (Dorsey and Hanrahan 1996b). On the other hand, Kato *et al*. (2000) used water droplet model with a discretized surface to represent water flow stains. As a result, various stains depending on the surface shape could be generated. There are some other related works. Self-organized cracks on Traditional Japanese Tea Cup could be expressed with 1/f fluctuation (Takagi and Cai 1998) and a method for rendering citrus fruits was suggested by Tokai *et al*. (1993). In order to express various shapes of the surface, fractal function is used. Also, Honami *et al*. (1999) generated dirty floor images caused by human traffic at indoor steps. In this paper, they simulated human traffic and the distribution of foot-print, and calculated the mass of soil and dust. However, these are no researches to express the dirty images of walls or roads, which often appear in landscape simulation.

3. WEATHERED IMAGE GENERATION

3.1. Architecture

This paper suggests a generation method of weathered images, which represent walls or roads. Figure 1 shows real pictures of a wall and a road.

(a) wall picture (b) road picture

Figure 1. Real pictures of a wall and a road

There are generally two types of features on the surfaces of walls and roads as the following.

1) There is some unevenness on the surface, and the roughness is different depending on the surfaces. Material images can be generated by combining several these fundamental images.

2) There are some dirty images caused by rain drops, cracks and so on. The patterns of the dirtiness are different, and can be generated by combining several kinds of fractal images.

Therefore, this method represents unevenness of the surface by placing black and white pixel patterns at random. We have investigated several kinds of patterns such as 2x2, 3x3, 4x4 and 5x5. And the fractal images can be generated by using fractal functions (Mukai *et al*. 2003a and 2003b) (Shigeoka *et al*. 2004). This paper describes the more details of the fractal image generation with fractal functions.

3.2. Material Images

In order to represent unevenness of the surfaces, black and white pixel patterns are used (Mukai *et al.* 2003a and 2003b). There are several types of patterns and the sense of the generated images is different depending on the size of the patterns. The larger the size is, the rougher the sense is. Figure 2 shows one example of the generated material images.

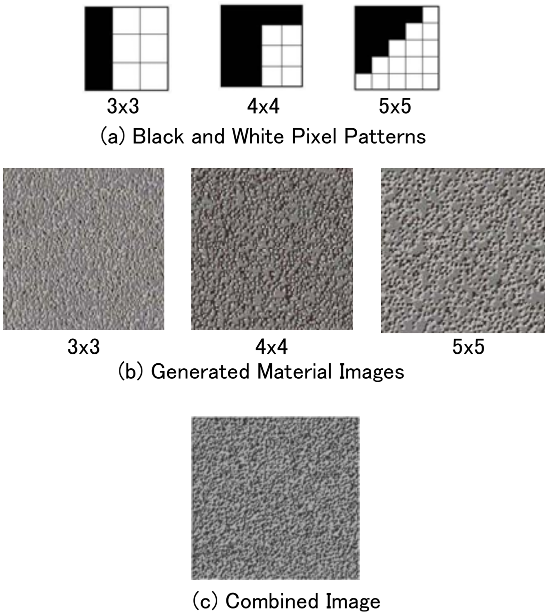

Figure 2. A generated material image

3.3. Fractal Image

This method uses fractal function to generate fractal images. Figure 3 shows the coordinate system of generators.

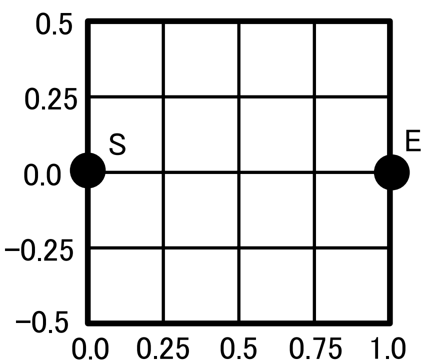

Figure 3. Coordinate system of generators

The control point of generators should start at the point of S (0.0, 0.0) and end at the point of E (1.0, 0.0). The line passing S and E is called *Base Line*. Other intermediate control points can be placed at any grid points. Fractal functions generate pictures by iterative procedure and usually draw lines; however, the purpose of this research is to generate dirty images caused by rain drops, dusts or cracks, so that only control points are drawn. Figure 4 shows the iterative procedure to generate an image with a simple generator of fractal functions.

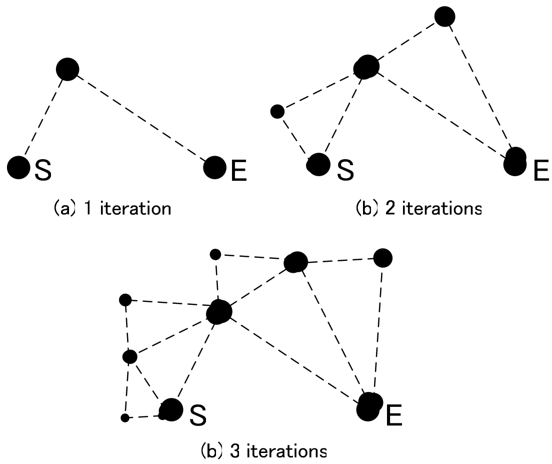

Figure 4. Iterative procedure of fractal function

In Figure 4, the size of the control points are shrunk depending on the iteration times to represent that the size of the generator is shrunk; however, actually the size of printed control points is constant. 13 iteration times of this procedure makes the image of Figure 5.

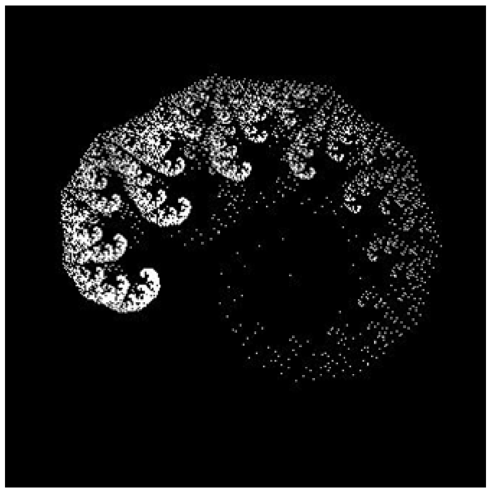

Figure 5. A generated image by fractal function

3.4. Base Line Rotation

The above procedure makes an image by iteration, which draws control points according to the base lines although the length and the tilt angle are changing depending on the iteration times and the part of the generator. This paper proposes the rotation of the base lines. Control points should be drawn according to the base lines, which are rotated 90 degrees counterclockwise. Figure 6 shows the iterative procedure with the base line rotation.

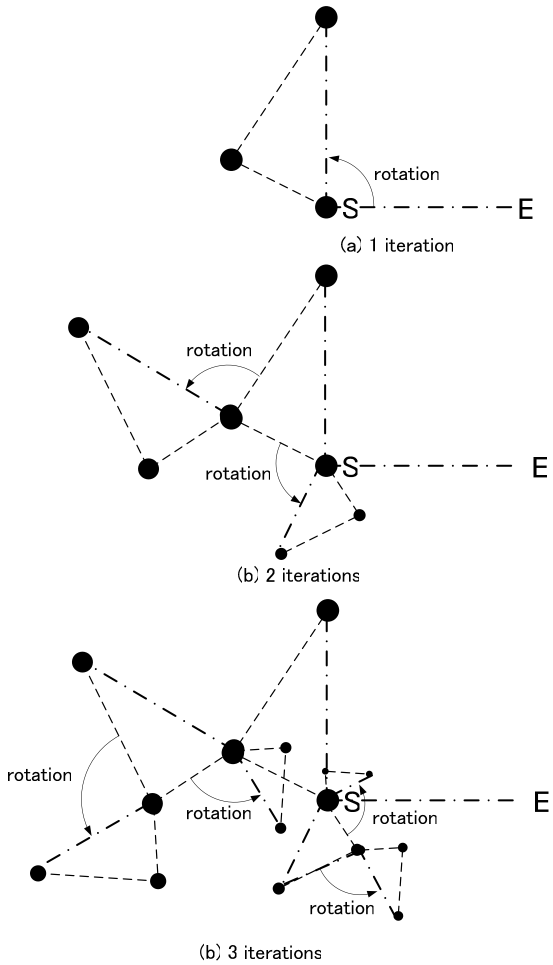

Figure 6. Iterative procedure with base line rotation

13 iteration times of this procedure with base line rotation makes the image of Figure 7.

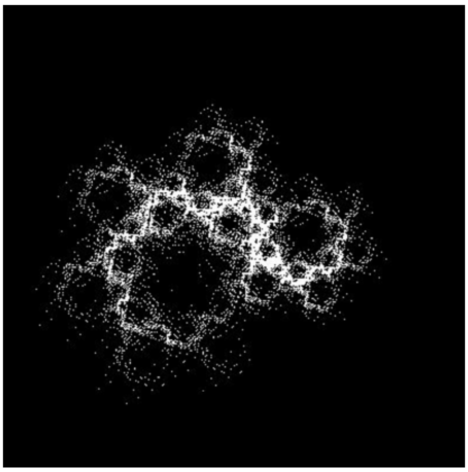

Figure 7. A fractal image generated with base line rotation

3.5. Image Translation

By the rotation of base line, different images can be generated. This is because the control points of the generator are drawn at the different positions. However, the different positions are in the part of a circle, which center is the start point of the base line. As a result, there is a tendency that the generated images have round shapes as we can see them in Figure 7. On the other hand, the actual dirty image of walls has a direction and it is sometimes not a round shape. Therefore, we have tried to translate the fractal images each time they are generated. The more the iteration time is, the more shrunk the size of the image is. Then, the translation length should be larger according to the iteration times. The translation length is defined as follows.

Translation length = Iteration time x Constant

Where, Constant is 20 [pixels]. Figure 8 shows the image with this translation. The generator and the iteration times are the same as Figure 5 and 7. The image is translated only in the vertical direction.

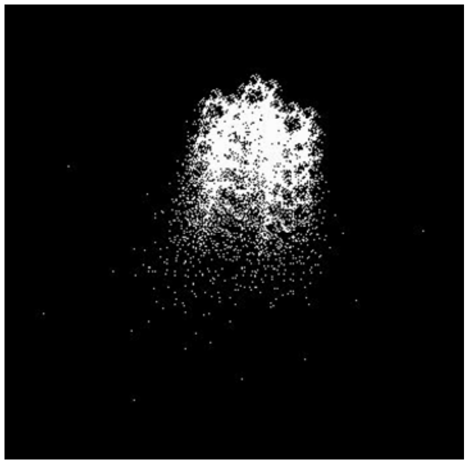

Figure 8. A fractal image generated with translation

Figure 8 has a feature that the shrunk images of Figure 7 are translated in the vertical direction. As a result, the generated image has a feature that the vertical length is longer than the horizontal. However, the upper part of Figure 8, which has a large number of iteration time, has many control points, while the below part, which has a small number of iteration time, has few control points. Then, the 29 images of 7 iteration times are shown in Figure 9. The round shapes seen in Figure 7 disappear and the vertical length of the image is much longer than the horizontal one.

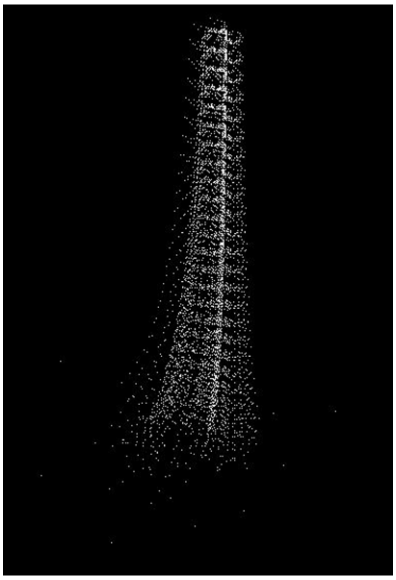

Figure 9. A fractal image with a large number of translations

4. EXPERIMENT

This proposed method has applied to generate a weathered image according to the real picture of a wall. Figure 10 shows the real picture of a wall.

Figure 10. A weathered image of a real picture

First of all, many fractal images are generated with generators defined according to the coordinate system of Figure 3. Then, the comparison between the generated images and the real picture (Figure 10) is performed by manual. As the result of the experiment, Figure 11 (a) has been selected as the generator and (b) has generated with the base line rotation. The iteration time is 7. (c) is another image generated with not only the base line rotation but also the translation, and the image is rotated to be fitted to the weathered pattern of the real picture (Figure 10).

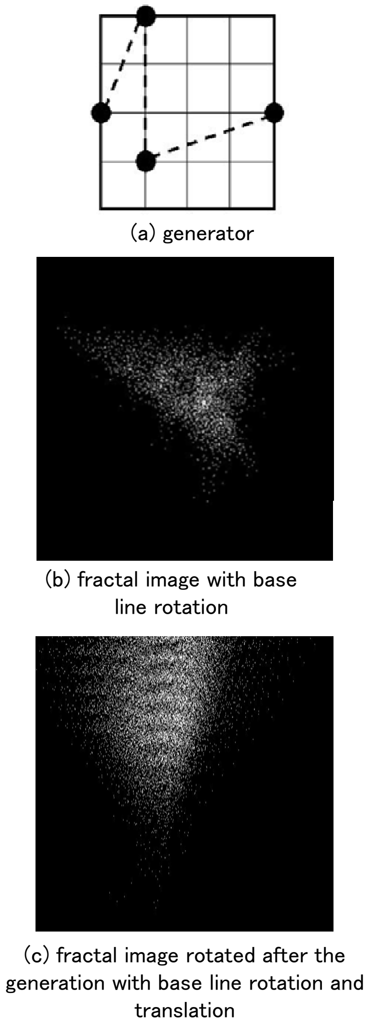

Figure 11. A generator and the generated fractal images

Finally, a weathered image has been generated by combining some images generated with the above method. Figure 12 shows the image. Figure 2(c) is used as the material image.

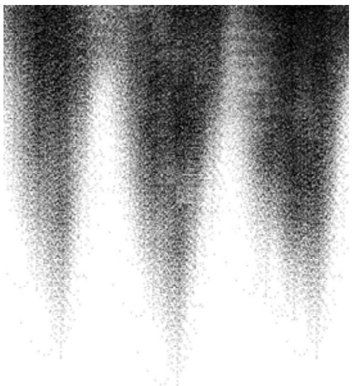

Figure 12. A weathered image generated with this method

5. CONCLUSIONS

This paper proposed a generation method of weathered images, which often appear in landscape simulation. In this model, a weathered image is composed of two types of images: material image and fractal image. Material images are generated by placing black and white pixel patterns at random, and variety of images can be generated by combining several kinds of material images. On the other hand, fractal images are generated with fractal function. Usually, fractal image is generated by iterative procedure, which draws the generator according to the base line. However, two types of changes are introduced in this paper. One is that the only control points are drawn and the line passing through control points are not drawn to generate fractal images. The other is the rotation of the base line, by which different types of images are generated. Also, this paper suggested the translation of the image. By the translation, the generated image has a directive feature. That is one direction length of the image is longer than the other. Finally, a weathered image has been generated by combining material images and fractal images.

With this method, weathered images of walls used in landscape simulation could be generated. However, there are some issues to be solved in the future as the following.

1) Automatic extraction of fractal generator: in this experiment, a fractal generator is selected by manual with comparison between pre-generated images and the real picture. The fractal generator should be automatically selected with the fractal image database.

2) Automatic combination of fractal images: in this experiment, fractal images are combined by manual with several images automatically generated by this method. The combining position of each fractal image should be automatically defined according to the real picture.

3) Colorization: this paper suggested the method that generates binary images. Gray scale image can be generated with the extension of this method; however, colorization should be taken into account.

We plan to investigate the above issues and apply the method to the landscape simulation, which has the computer graphics models of our university and the neighborhood

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