Environmental Design using Fractals in Computer Graphics

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Computer graphics have developed efficient techniques for visualisation of the real world. Many of the algorithms have a physical basis, such as computational models for the light and the shadow, models of real objects (buildings, mountains, roads and so on) and the simulation of natural phenomenon. Now computer graphics techniques provide the virtual world with a perception of three dimensions. The concept of the virtual world and its technology have been expanding and intensifying in recent years. Almost everything in the real world has been simulated in virtual world.

When it comes to a terrain model, what we need is labour and time. But now it is possible to simulate terrain like the real world using fractals in computer graphics with a very small program and small data set. This study aims to show how to build a real world impression in the virtual world. In this paper the authors suggest a landscape design method and show the results of its application.

Keywords: fractals, polygon-reduction, computer graphics, virtual world and collaboration

Introduction

Fractals have been used to describe spatial patterns in many landscape-level applications. One such application has been used to measure the geometric complexity of landscape features. Moreover, fractals in computer graphics offers not only a way to create scenes which are startlingly life like, but also a way to create scenes filled with infinite detail. The statistical self-similarity of fractal shapes is inherent in the natural world and may be exploited to create a new environment, which is harmony with existing landscape.

But when we build real world by fractals, we have some problems considering economic efficiency and constructive difficulty. How can we build real world? This is a polygon-reduction problem. In the virtual world that we simulate it is a big problem to deal with larger 3D models in real time.

Nowadays polygon reduction tools are solving this problem. Those tools optimise the models by reducing the number of polygons while preserving all model features, such as textures, materials, colours, object/scene, hierarchy and volume. In real world we are living it's also possible to apply polygon reduction to design concept considering the relationship between distance and landscape.

In this paper, the authors have examined the applicability of landscape design utilising fractals and polygon reduction. Consequently, the design of coastal facilities is produced by this supporting method. And, it is shown that this landscape design considering fractals and polygon reduction can be one of reasonable design methods to reflect the
naturalness of coastal zone and make real world through virtual world. To design coastal facilities using new kind of approach, we adopt the coexistence of harmony and contrast. In other words design object seems to be harmony with landscape from a distance. But it seems to be contrast with landscape as we come nearer. In this case it’s possible to realise the design idea based on fractal theory and polygon-reduction principle.

**Project W**

The Local government of W in Japan wanted to secure building site on the sea considering growing needs of commercial area. But the area surrounding the site is famous for beautiful scenery involving islands, and the residents did not want to harm the scene for making landfill. Therefore local government wanted to make man-made island which looks like a natural island. But the problem was how to make a man-made island looks like a natural island.

**Modelling**

Before designing the shape of man-made island we need to review the view from famous viewpoints. The distance between viewpoints and the site is more than 700 meters. First of all we need to make topological model of man-made island and it was never attempted before. Because we always made a model of topology from map which contained contour line. There is no reference to make it. No map, no picture. Therefore we copied peripheral topology to the site, and described rough shape of the island by trial and error. For processing that kind of process we found some characteristics on topology in that area. If we design man-made island looks like a natural island, it must have same characteristics as peripheral topology. So we began to study how to make a model with same features, and learned that fractals could help us to visualise it in virtual world. We measured fractal dimension of this area and applied it to make topological model. Finally we succeeded to make a virtual model of man-made island using fractals and it looked like a natural island because they had same fractal dimension as surrounding area (figure 1). But can we call it the design?

**Inspiration**

When we were making the topological model, the designer got inspiration from the wire-flame of the model (figure 2). We use models to describe a natural scene in virtual world but we don’t try to use these models to realise it in real world. He mentioned this concept as “Demodeling.” (the term “Demodeling” was used for the first time in the keynote paper of CAADRIA’99 and defined by Tsuyoshi Sasada in his keynote speech in 1999).

From long experience of modelling and rendering, people who know about CAAD understand the idea of an object on a 2D grid like a pixel and 3D grid like a solid. The idea came from that kind of thinking. After we got the idea, we designed the shape of man-made island and began to doubt the possibility of construction. To make it realise we built up design team.

**Collaboration**

The design team was composed of an architect, harbour professional and artificial professional. We always suggested CG for their understanding and other professionals added their view by speech or drawings. Then we refined the design through iterated design meetings.

**The First Design Meeting**

We made a CG still image based on the idea of
designer and showed it to other professionals for checking doubt the possibility of construction (figure 3). The answer was yes.

The Second Design Meeting

Harbour professional suggested the plan as figure 4. If the cubes were placed on seaside they would make a weak the power of wave and there was no need to put the tetrapod in front of man-made island.

The Third Design Meeting

Finally the design was refined by the collaboration of the design team and some still images were produced for activity on the site as follows (figure 5).

Observations

Fractals

Mandelbrot’s fractal geometry provides a way of measuring many natural shapes. Researchers have applied fractals to describe special patterns in natural scene or landscape. Most of this work used fractals to characterise the features in landscape. In other work the fractal dimension of individual landscape features was measured as an index of classification. Some of them analysed the fractal dimension of Japanese garden. Lam (1990) used fractals to discuss the spatial complexity of three land types. Milne (1990) applied fractals to estimate the probability of locating a landscape patch shape; in most cases, a single fractal value was determined for the entire landscape for selected cover types or for all cover types (Turner, 1990). But fractals is used for not only describing nature but also making nature.

Process

Considering the kind of characteristics of fractal, this is a perfect concept for making new land on sea. When we make a terrain model we need to scan the map of topography and then drew every contour line. It need many working hours and labours. More we can say topological model is the largest part of the virtual world and most time-consuming work.
Figure 5 (left). Activity

Owing to fractals it’s very easy to generate huge topological model from small data. Sometimes we can make a non-existing model like a man-made island by simple program. In Hollywood they make planet-like virtual world using fractals. But we can use it for real world.

The process of making man-made island is as follows.

- Analyse fractal dimension of surrounding area of the site
- Copy the representative model of the area to the site
- Drew the contour line in interval of 16m
- Make a terrain model using modeller like a FormZ
- Save as DXF format
- Convert to fractal terrain model using transformation tool
- Get fractal terrain model as dense as you want

Sasada Laboratory developed this transformation tool early in 1991 and it was often used for making model of rocks on the beach. It needs the fractal dimension and iteration number. After we got the fractal terrain model of man-made island, we made a photomontage to review it from famous viewpoints. It looked like a natural island as local government wants.
and there are two kind of methods to build it. One is to use artificial rocks on concrete wall and the other is to build a small mountain in front of the site for hiding it from famous viewpoints. The simplest way to satisfy the client and residents is to use artificial rocks because it is easy to get it in the market and to combine it considering construction on sea. Therefore we considered the detailed model of man-made island from all angles. The distance between the site and viewpoints is more than 700 meters and there is no need to build it as fractals showed. We made some CG still images using Polygon-reduction tool and compared it with each other considering the relationship between the landscape and the distance.

**Polygon-reduction**

When we make a CG for environmental design, we need huge data set for example, mountains, main building and its peripheral buildings, trees, roads and so on. For fast rendering, sometimes we replaced detailed model to simplified model. But the quality of CG is inversely proportional to the speed of rendering. Therefore we need to make two kinds of models i.e. simplified model and detailed model for fast rendering and high quality. And when we make CG animation we replace it each other according to viewpoint and its range. In VRML it used LOD (Level of Detail) according to scene for saving time to display on browser.

For solving those problems, nowadays some polygon-reduction software is used. The software simplifies polygons while preserving whole feature of the original shape.

**Process**

We tried to make a simplified man-made island for making artificial rock panel. Because the panel is need to make a model of it. We applied polygon-reduction software to make a simplified man-made island. The results are as follows (Figure 6). If you look at those mapped models from remote viewpoints, you can’t figure out the difference between them.

**New method**

Through those process we realised that using artificial rocks seems to be engineer not designer. We need another method to realise man-made island. At that moment, designer got an inspiration from those simplified models (Figure 2).

Therefore we decided to divine man-made island into green and cliffs. The model of green came out from fractals and cliffs came out from polygon-reduction.

**Process**

- Get fractal terrain model as dense as you want
- Divide its area into green and cliffs
- Replace concrete blocks to cliffs using transformation tool
- Combine green and concrete blocks

When we replace concrete blocks to cliffs, we added each height of concrete blocks referenced from fractal terrain model.

**Conclusion**

Project W show that it is possible to get an idea of designer from computer graphics technology. The idea is quite original, but wisdom of collaborators is added. In this project we attempted a new design method.
based on fractal and polygon-reduction (figure 7). We would summarise our view as follows.

- CG is a design tool and also it can be an inspiration tool.
- The visualised idea stimulates creative design.

**References**


**Web References**