自然景観エディタ

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山，湖，森などの多数の自然物からなる景観の幾何モデルを構成するエディタを作成した．従来から，フラクタルを始めとして，確率モデルを用いて自然物を表現する試みは多くなされているが，多数の自然物からなる景観全体をモデル化する手法はあまり提案されていない．本稿では，著者らが既に提案した準大局的スペクトル合成法（Semi-globalized spectral synthesis）をもとに，自然景観全体をモデル化するためのプレビュー用エディタを報告する．本エディタでは，景観の部分部分をプリミティブと称する確率モデルで構成し，これらを集合演算でつなぎ合わせ，景観全体のモデルを構成する．諸パラメータの設定には，ビジュアルなエディット画面で対応し，直感的な指定ができるようにした．その結果，計算機の初心者でもある程度の"三次元スケッチ"が可能となる見通しを得た．

A previewing system for 3-D natural scene description

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This paper presents a previewing system for 3-D natural scene description, based on semi-globalized spectral synthesis. The method of semi-globalized spectral synthesis provides a primitive, as a semi-global expression of the scene, and functional operations through which the whole scene model can be defined from the primitives. The functional operations on the primitives include "set-theoretic operations" such as, sum or subtraction between the primitives. The previewing system allows a user to visually and intuitively specify the primitives and the functional operations, in order to obtain the final model of the whole scene. The experimental result demonstrates the practical efficiency of the previewing system.

1. Introduction

Stochastic spectral synthesis was originally introduced as one of the visualization methods of fractal objects [3]. Its available range would be much wider if we could know statistical characteristics, such as a power spectrum or autocorrelation function, of the objects to be depicted. Semi-globalized spectral synthesis [1] was recently proposed to describe a 3-D natural scene consisting of many natural objects, each of which may have distinct statistical features. The descriptive power of the method was then illustrated by the images generated. The results have led us to believe that the method can provide a way of intuitively modeling of the 3-D natural scenes. The next step is to make it usable.

A previewing system of semi-globalized spectral synthesis is therefore presented in this paper. The aim of the system is to provide an interactive tool which allows a user to easily obtain a desired image of the 3-D scene using the low-dimensional characteristics and functional operations in the method. The application fields of the system is then supposed to include those where the generated models of natural scenes are crucial tools for graphics rather than as precise scientific visualization. Film-making or entertainment industries are such examples.

2. Outline of the method

The low-dimensional characteristics are used for designing a *primitive*, not for obtaining the "global" model of the 3-D scene. The primitive is meant to give a "semi-global" expression of the whole scene.

The geometric data of the primitive is obtained from the put data listed in Table 1. The primitive Z(u, v) is then a random field defined by:

$$Z(u, v) = \sum Y_k(u, v);$$

$$Y_k(u, v) = x_{2k-1}(a_{2k-1}u + b_{2k-1}v) \cdot x_{2k}(c_k u + d_k v);$$

$$x_n(t) = \int \sqrt{S_n(f)} \exp(i2pft)\, dM(f).$$

The above Y_k is called a stochastic wave, whose peak position is assigned by (I_k, J_k) in Table 1, where the number of the stochastic waves is denoted by N_W; the stochastic processes x_n are referred to the 1-D components of Z; and the direction vector (a_i, b_i) are used for defining Y_k from a pair of the 1-D components.

The *functional operations* on the primitives are then introduced for the globalization process. In the sense of stochastic modeling, the functionals described below can be defined on any stochastic models which takes non-negative real values. After generating the above x_i $(1 \leq i \leq 2N_W)$, the 1-D processes x_i are shifted to take non-negative values.

First consider the functional operations defined on a single stochastic model Z(t), where **t** = (u, v).

(a) Cut operation $(\cdot)_c$:

$(Z)_c(\mathbf{t}) := \max\{Z(\mathbf{t}) - c, 0\}$,

where the constant c is specified by a user. Meaningful results are obtained with $0 \leq c \leq \max\{Z(\mathbf{t})\}$, whereas the user do not have to know in advance the meaningful range of c.

(b) Scaling operation $(h\cdot)$:

$(hZ)(\mathbf{t}) := h \cdot Z(\mathbf{t})$

where the positive constant h is specified.

(c) Turnover operation $r(\cdot)$:

$r(Z)(\mathbf{t}) := \max\{Z(\mathbf{t})\} - Z(\mathbf{t})$.

The turnover operation in (c) is used next to define a subtraction operation which works on a pair of the primitives.

Table 1 Input parameters for a stochastic wave

Symbol	Name/ Meaning	Remark
N	(square) domain size of primitive	$N = K^2$
N_w	wave number	
(I_k, J_k)	peak position of the k-th stochastic wave	$k = 1, \ldots, N_W$
(a_i, b_i)	direction vectors	$i = 1, 2, \ldots, 2N_W$
$S_i(f)$	power spectra of 1-D components	
M; Δt	data size & unit interval of 1-D components	

Next the functional operations on a pair of the models $Z_1(t)$ and $Z_2(t)$ are defined. They are called set-theoretic operations, for convenience:

(d) boundary operation ($\setminus$):

$$(Z_1 \setminus Z_2)(t) := \begin{cases} Z_1(t), & \text{if } Z_2(t) \le 0 \\ 0 & \text{otherwise.} \end{cases}$$

(e) Sum operation (+) :

$$(Z_1 + Z_2)(t) := \max\{ Z_1(t), Z_2(t) \}.$$

(f) Subtraction operation (-):

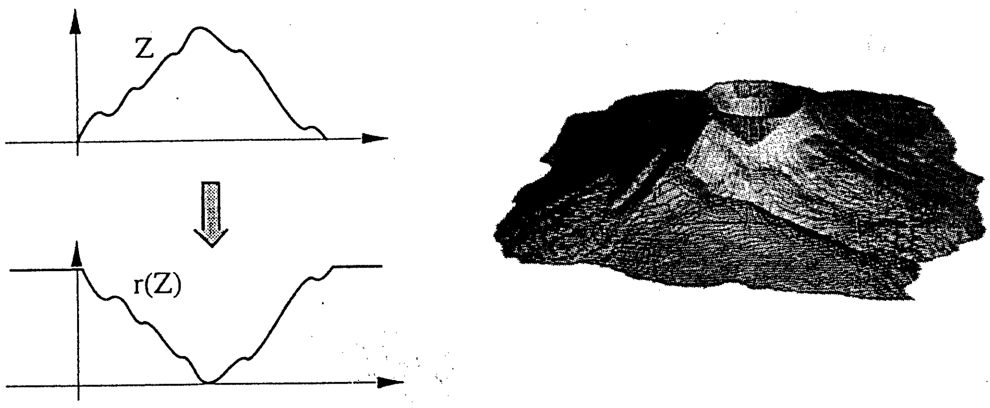
$$(Z_1 - Z_2)(t) := \min\{ Z_1(t), r(Z_2)(t) \}.$$

The practical meaning of the set-theoretic operations (d) - (f) are rather intuitive in the sense that these operations may represent directly the geometric relations between natural objects. For example let us consider the subtraction operation in (f). Fig.1 shows a typical use of this operation. Then the turnover operation in (c) is illustrated in Fig. **1** (a). The volcano model in Fig. **1** (b) is defined using the operations (a), (b), and (f). The concave part of the volcano model is generated by the subtraction operation. Since the model are then wire-framed, it is easy to see the depth of the concave. In this case, the volcano model may correspond to the user's direct impression; "The top of some mountain looks *subtracted* to leave the volcano over there".

The set-theoretic operations described above are meant to provide a way of intuitive descriptions of 3-D scenes, rather than that of physically faithful expressions.

3. Previewing system

The functional operations may be useful in the "intuitive" design of 3-D scenes. Since these operations should be performed interactively,



(a) $r(Z)(t) := \max\{Z(t)\} - Z(t)$ (b) $(Z_1 - Z_2)(t) := \min\{Z_1(t), r(Z_2)(t)\}$

Fig.1 Turnover and Subtraction

we need to construct an interactive system based on the method. To demonstrate the method's efficiency, the "previewing" system for 3-D scene depiction is developed.

3.1 Previewing Editor

The main task of this system is *previewing*; the final image or animation of the generated 3-D scene may be recreated by other machines. The output data are those of colored polygons (or triangles), which prescribe the geometric structure of the scene and its color attribute. The editor screen is divided into 5 parts, as shown in Fig. **2**:

[a] Command display/selection view (Fig.**2**(1))
Command menu of the system is displayed on this part of the monitor screen. Scrolling commands is also available by picking the top or bottom triangle.

[b] Primitive view (Fig.**2** (2))
Designing primitives is done through this view, where each primitive is displayed in a smaller window. Cut or scaling operation is performed using this view. Scrolling to left or right is necessary for additional primitive design.

[c] Scene display view (Fig.**2** (3))
The perspective view of the whole scene is displayed on this part.

[d] Contour map view (Fig.**2** (4))
The height at a point in the domain where all the primitives are defined is distinguished by its color. Positioning primitives and the set-theoretic operations are performed using this view.

[e] Message display and key-input operation view(Fig.**2** (5))
This view is used for displaying messages, such as "enter a command", and "wait for a while...", or for inputting numerical information, such as the scaling factor h in (b) and c for the cut operation in (a).

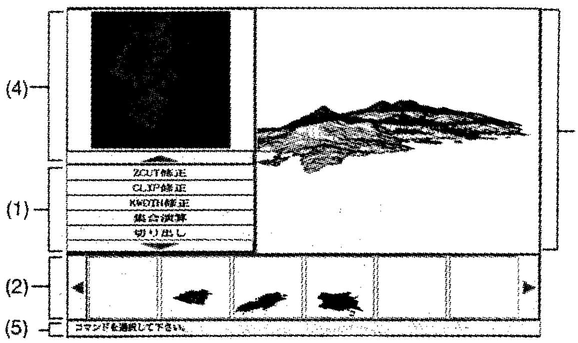


Fig. 2 The Previewing System

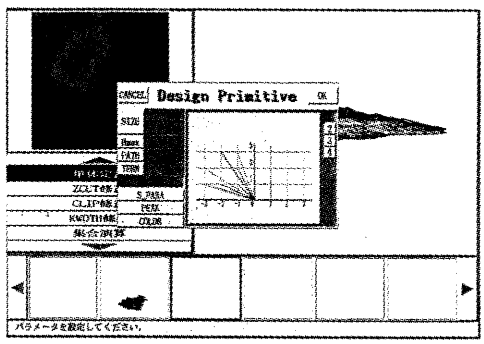


Fig. 3 Primitive Design Window

3.2 Editing process

A 3-D natural scene design is achieved by repeating (i) design and modification of primitives; (ii) positioning primitives into the whole scene through affine transformations and set-theoretic operations; and (iii) displaying the whole scene.

Let us select a command: "design primitive". The window, indicating "Design Primitive" in Fig. 3, then appears. In Fig. 3, a new primitive is to be made in the small window (the third from left) of the primitive view. The parameters listed in Table 1 are visually assigned, using the "Design Primitive" window and the primitive view. For example, by clicking the menu "PEAK" in the top-left screen in Fig. 4, the lattice domain is displayed, where the peaks (I_k, J_k) are positioned by mouse-picking. If we select "S-PARA" in the "Design Primitive" window, then the spectral

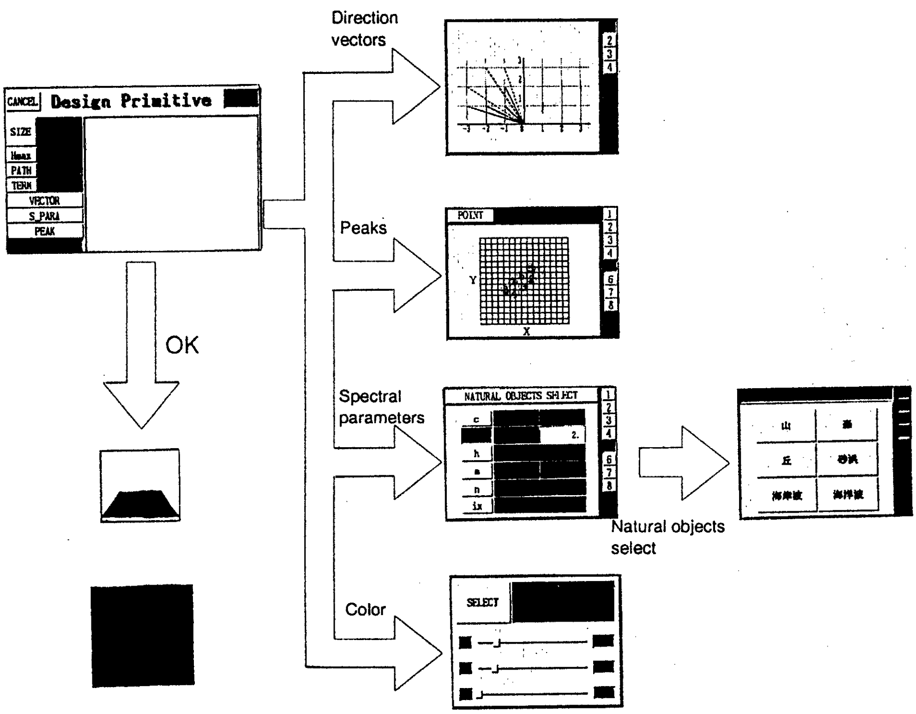


Fig. 4 Primitive Design Procedures

are numerically assigned. In addition, in picking "NATURAL OBJECTS SELECT", then we can access the database of the spectral parameters which stores previous results, as shown in Fig. 4. The color attribute is also specified for a primitive. After several primitives are defined, they are combined to make a whole scene, using the functional operations. Fig. 5 shows a sum operation example. The primitive which is in the third window from the right-hand side of the primitive view is then about to be added to the global model of the whole scene. In the contour map view, the primitive is picked up and moved by mouse operations. The result of this operation is displayed in the contour map view and in the scene display view, as shown in Fig. 3. Primitive design process and the functional operations among the primitives are repeatedly used until the desired model is made.

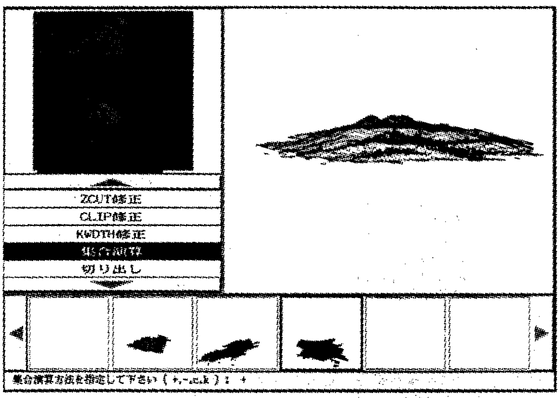


Fig. 5 Sum Operation Example

4. Experimental result

The previewing system is currently constructed on the Hitachi workstation 2050G (68030-25MHz). The hardware facility includes hidden line elimination and z-buffer algorithm, which are used for rendering the scene model generated.

Several monitors, who are all unfamiliar with computer graphics and computer itself, tried to make a 3-D sketch using the previewing system. Before the experiment, a few days were spent for the monitors to know how to use it. Each monitor was then asked to describe a 3-D scene freely using the previewing system, while he or she used the system at most two hours a day. Fig. 6 shows a 3-D scene example designed by one of the monitors. She needed totally ten hours in making the scene data,

Fig. 6 Scene Description Example by a Monitor

which include its color and geometry (represented by triangles). The six

primitives were then designed by her for the terrain in the distance, with one primitive for the sands and another for the wave in Fig. 6.

Fig.. 7 was made by a skilled user. He needed totally four hours in making the data for each scene. In designing a complex scene, it should be noted the set-theoretic operations applicable to color design of the scene. In the case of the scene shown in Fig. 7, for example, the boundary operations were performed to make the coastline. Then the sands model Z_1 was cut according to the fractal type primitive Z_2, which models the coastline. Then the color of the sands part of $Z_1 \setminus Z_2$ is that of Z_1.

The experimental results led us to believe that the previewing system can provide users intuitive guidances for 3-D scene generation. Though some monitors required totally 10 hours or so to obtain the final scene models, we cannot estimate whether the results are sufficient or not. In any case, however, it is desired that the total time for the editing process should be rather lessened. This will be achieved soon, according to the increasing power of the hardware facilities.

The reality achievable by the method may be comparable to other approaches for stochastic spectral synthesis [2], as demonstrated above. The experimental results led us to expect that the descriptive power of the method is not exhausted, even if the generated models are wire-framed, without sophisticated rendering techniques. As mentioned earlier, the method may not be applicable to the fields where rigorous scientific visualization is required. However it is also understood that simulation-based approaches cannot be almighty under the currently available workstation environment. There are actually many natural phenomena which cannot be visually simulated. The next possibility is therefore to make a hybrid approach that combines the method with other simulation-based approaches, in order to reach a virtual world of higher quality and reality.

5. Summary

We have developed the previewing system for semi-globalized spectral synthesis. In editing a 3-D natural scene, we can easily design a primitive by using the system, which allows us to visually specify several parameters for the primitive. In addition the system provides the functional operations for scene description, through which the primitives with distinct spectra are effectively combined. The obtained results demonstrate the practical efficiency of the method.

The current version of the system does not treat clouds and trees(at a closer look). A more sophisticated rendering approach, such as a ray-tracer, will also be required to achieve more realistic description of natural scenes.

References

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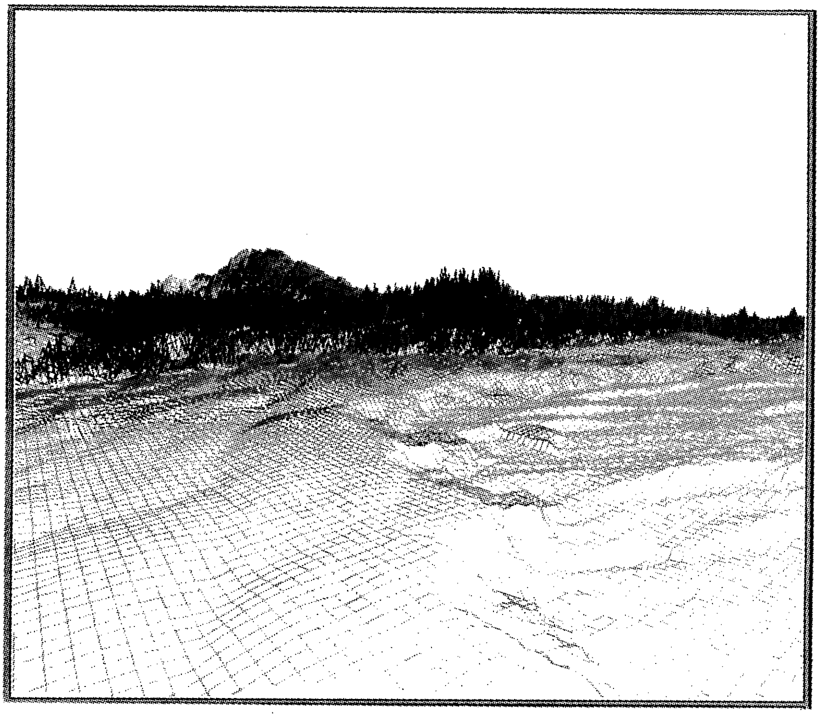

Fig. 7 Lakeside Scene