Simulation of the Radar Ground Clutter Based on DEM

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Abstract

The simulation of ground clutter is the key and knot problem in radar simulation system. The simulation of ground clutter based on DEM is studied. It is introduced how to use fractal arithmetic to produce random digital elevation. After obtaining the orographic's height, draw the 3D terrain with the OpenGL technology, in order to realize the demonstration of 3D terrain. Based on DEM, terrain is divided into many simple grid surfaces. This geometry is constituted by four adjacent high points of the terrain. It is detailed to discuss how to account the power of each unit ground clutter by using radar equation and digital elevation, use the superposition principle to superpose each unit power, and then achieve the ground clutter of entire ground. The entire power of ground clutter wave is got in to unitary processing, correspond it to 0~255 grey level. Through the BMP picture's read-write, the grey level which will obtain was written in the BMP file in order to realize showing of the entire power of ground clutter. The results show that it is fit for what the project needs.

Keywords: *3D terrain, Fractal interpolation algorithm, DEM, ground clutter*

1. Introduction

Radar in the process of training and development needs a lot of radar clutter data, but the real clutter data can't be in a short period of time, and cost is very high, with the development of computer simulation technology, simulation on computer every link of radar signal processing is becoming more and more easy, so using computer simulation technology to simulate radar clutter is a very good method.

Ground clutter simulation based on DEM is DEM terrain data and ground clutter characteristic organic union, namely, according to the characteristics of the terrain data and the principle of radar clutter calculation mathematical model, and then through the software programming, shows the result of clutter simulation on computer.

Research the main content of this paper is to study based on the digital elevation model of the ground clutter simulation problems, using fractal algorithm generate random terrain elevation data. On the basis of elevation data, The ground split into many scattering characteristics known simple geometric scattering surface unit, which is calculated by using the radar equation and analytic geometry of each unit of the ground clutter power, then using superposition principle for each unit of power to overlay, realize the whole calculation of ground clutter, and using OpenGL technology to display.

2. Three-dimensional terrain visualization

Major headings are to be column centered in a bold font without underline. They need be numbered. "2. Headings and Footnotes" at the top of this paragraph is a major heading.

2.1 The commonly used method for generating topography

At present, the commonly used method for generating topography can be roughly divided into the following three types:

Surface is used to generate three-dimensional terrain. This is a traditional method for generating topography. This method because of its complexity, the mathematical calculation for complex scenarios, the large amount of calculation, but also to adopt more complex surface splicing technology, is only suitable for small and medium scale of data processing.

Remote sensing technology generated three-dimensional terrain. This method is often used in the simulation of real. In texture mapping technology, on the basis of the study area of remote sensing image and terrain together, get a more realistic 3 d visual effect, is a good way to simulation the objective world.

Fractal technology generated three-dimensional terrain. Fractal geometry has the infinite and the rule of statistical self-similarity, it complicated scene with recursive algorithm can be used to generate simple rules, can produce any level of detail, provides us a good description general mathematical model of surface shape.

Terrain generation technique of this paper will adopt the method of fractal geometry technology to generate the terrain. The final implementation is the use of fractal geometry to achieve.

Fractal terrain model can be roughly summed up as Poisson step method, Fourier filtering method, themed point displacement method, successive random increase method and band-limited noise accumulation method and five classes. In the above several kinds of three-dimensional terrain modeling method, and to rapidly generate terrain of the midpoint displacement method most widely used, its characteristic is concise and quick, and can realize high randomness, there is no clear sense of repetition. This article will focus on this paper this method is used to generate three-dimensional topographic map, the final implementation is also generated by random midpoint displacement method of the specific information of terrain.

2.2 Random midpoint displacement method

Midpoint displacement method also known as random midpoint displacement method, is the most simple and classic method, is the direct application of fractal Brownian motion.

This article adopts the two-dimensional space of the fractal interpolation algorithm namely Diamond - Square algorithm, known elevation points from the given terrain grid data, through the Diamond steps and Square calculation, complete terrain grid refining and data calculation, algorithm steps are as follows:

A. initialize the two-dimensional (N+1)×(N+1) DEM data matrix(N=2n), and the four corner is set to the same height. As shown in Fig.1 for a 5×5 array Diamond-Square algorithm process. In Fig.1 (a) the height of the four angles of value to initialize, shown in Fig.1 new value into the black, existing point displayed as grey.

B. diamond step, as shown in Fig.1 (b), taking square four point, in the square midpoint to generate a random value, mid-range is the average of the four corners plus a random quantity is calculated.

C. square step, as shown in Fig.1 (c), pick up at four o 'clock every form a square (diamond step compared to the square rotated 45 degrees), the average Angle value plus the same as the diamond step random quantity, calculate the mid-range of each edge.

D. change the scope of random variables, to iterate the process, until the number of reach regulation, as shown in Fig.1 (d), (e) shown below.

In step 3 using the virtual net. A point on the side of this is because in the original square (except square corner four bars) only three neighboring points, in order to unified algorithm had to make up a virtual point, through the adoption of fractal interpolation method, which makes the grid within established a link between adjacent points, so as to make the synthetic body interior excessive more natural; In addition, the fractal algorithm is actually a kind of recursive algorithm, which generates the body has a self-similar and precise structure.

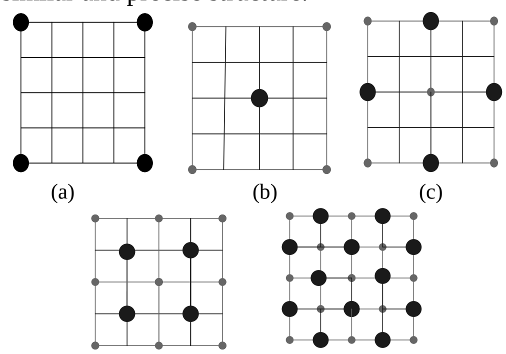

Fig. 1 Diamond - Square algorithm

2.3 Generate terrain

Terrain simulation algorithm uses random midpoint displacement method, through the OpenGL implementation.

Use OpenGL display lists of the method to texture, according to the terrain height value according to different color, first with a child function statistics the terrain height value, record the topography highest one-third and two-thirds, according to a highly values its relationship with the two values to color in. When the coating color is paint points according to the height values its relationship with the two values to select the required color. In this article, more than two-thirds of the height of the display is white, two-thirds more than a third below to display as the gray, a third below the display for the green. Fig. 2 for no terrain texture map light conditions.

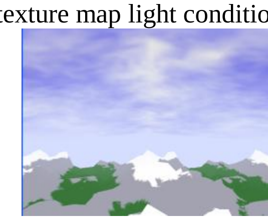

Fig. 2 Terrain texture map illuminated

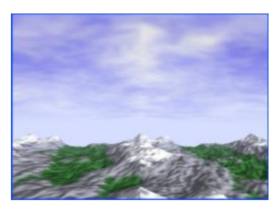

Fig. 3 The terrain texture map is to light

By above can see shape looks effect is not true, in order to ensure that objects according to reality, must display the three-dimensional view shade cancellation due to the object itself or keep out each other and cannot see lines and surfaces. Can meet recognition include blanking processing and visibility test two process. Through the blanking process to ensure that the part is not visible or obscured by screen, through considerable visibility test calculation and drawing of part of Yuan can meet. You can see the terrain texture map has been lighted in the Fig.3. Program flow chart can be shown in the Fig.4.

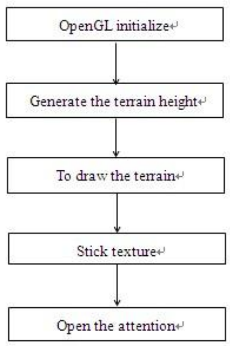

Fig.4 The flow chart of program

2.4 Topography control

Square is not the same, the size of the generated graphics are not the same. If the square size is 2, the graphics as shown in Fig.5,which is a program to generate a 2×2 square, and according to the steps diamond and square, the height of the generated values, to display to the screen.

The Fig.6 shows that the square size hours, program drawing is not detailed, the detail is not rich, the size is more than 10 is open up the space is very big, operation time is long.
Finally, select the size of 8, graphics as shown in Fig.6.

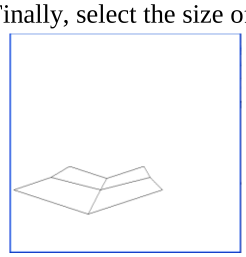

Fig.5 2 of size terrain meshes

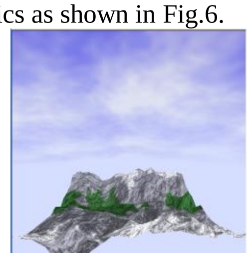

Fig.6 8 of size when the when terrain texture map

If you want to change or control of terrain, that can change the Diamond-Square algorithm with random values to achieve. In order to get the random value change, will set the seed value. In order to be able to interact in the program, this paper set the seed for the input values. So you can determine the terrain, as shown in Fig.7. Also, by changing the seed values can have different terrain.

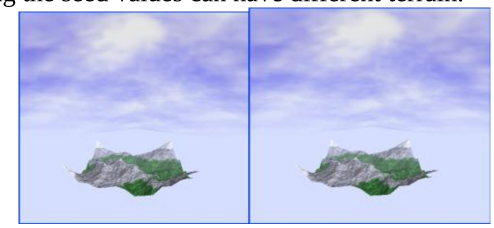

Fig.7 Two moments before and after the seed value to a fixed value when the topographic map

Terrain ups and downs can use the limited value of the random variable range scale to control. Scale of the initial value is 2-k, by controlling the value of h to control the terrain ups and downs, h is bigger and the terrain is flat, h is smaller, the more rugged. As shown in Fig.8.

Fig.8 The same random seed different terrain roughness

3. The power of radar land clutter

Radar ground clutter is the emphasis and difficulty in radar simulation system, through the digital elevation model, can realistically simulate real terrain, through the formula to calculate ground clutter power can be calculated out.

3.1 Ground clutter power calculation

Clutter power calculation equation:
Set a radar transmitted power is P, and radar antenna gain is G, radar antenna R is in the distance between the target power densities S as follows:

$$S = \frac{P_t G_t}{4\pi R^2} \tag{1}$$

Target irradiation by electromagnetic wave, will produce scattering noise. Target point with the size of the scattered power of emission power density S and the characteristics of target. Use a cross-sectional area to represent the scattering characteristics of target. Assumes that the target will receive the power without loss of radiation, the target to accept area is σ, namely, the radar cross-section .then target scattering power p2 can be obtained as follows:

$$P_2 = \frac{P_t G_t \sigma}{4\pi R^2} \quad (2)$$

Assuming $p_2$uniform radiation, effective acceptance area of radar receiving antenna is A_r, is received at the receiving antenna noise power p_r is:

$$P_r = \frac{P_t G_t A_r \sigma}{(4\pi R^2)^2} \quad (3)$$

The calculation of radar cross-section σ:

Is said target radar cross-section σ in the direction of radar receiving antenna scattering waves a measure of the ability. It is an equivalent area, when the area of radar intercepted by the irradiation energy isotropic to scatter around, in a unit solid Angle scattering power, equals the target to the receiving antenna direction within a unit solid Angle scattering power. So the target topography is important for σ. By DEM terrain data is known, the height of the grid four locations each are not identical, so the ground is not necessarily a plane, but a curved surface, the curved surface on the radar beam sectional area; the difficulty is very large. But in the case of accuracy is not high, the ground can be seen as a plane, before ask radar cross-sectional area, must take the radar beam and the Angle of the grid σ, and the Angle and pitching Angle with radar, target terrain slope on the grid. Pitch Angle can be obtained by radar state, the problem is due to the terrain slope. As shown in Fig.10, set a ground area of S_1 and the radar cross-section S_2, and the Angle β with the ground for the target grid, radar beam with an Angle α of the grid, each grid width are I.

$$S_1 = \frac{I^2}{\cos\beta} \quad (4)$$

$$S_2 = \frac{I^2}{\cos\beta}\sin\alpha \quad (5)$$

Problem into cosβ, sinα, and finally, we concluded that the two results in two steps below:

Step 1: calculate the normal vector of the ground.

Set of four adjacent terrain height point in DEM grid, because the grid represents real terrain is a curved surface, and the surface normal vector would be difficult to calculate, I in our grid spacing is not very big, we can approximate the plane according to the surface, as shown in Fig.9, take four grid A1A2A3A4 in three, a total of four kinds of method, they are: A1A2A3, A1A2A4, A1A3A4, A2A3A4. Obviously grid A1A2A3A4 in at four o 'clock as three points are coplanar. With any of these four triangular surface normal vector approximation to replace the vector topographic grid method.

Take A3A4 midpoint A5=［（x_3+x_4）／2,（y_3+y_4）／2,（z_3+z_4）／2］,with A1A2A5 three points of surface normal vector $\vec{F}$ instead of the normal vector of the terrain mesh.

Try to vector $\vec{F} = (x, y, z)$.

$$\cos\beta = \frac{|z|}{\sqrt{x^2 + y^2 + z^2}} \quad (6)$$

Step 2: calculate the Angle of radar beam and terrain grid.

Observed in Fig.10 shows the radar beam and terrain grid of the sine of the Angle value is equal to the radar beam and ground normal vector included Angle cosine cosγ. So the question into the radar beam and ground grid method vector two 3 d vector Angle. A radar beam vector is $\vec{u}$, the surface normal vector is $\vec{v}$. The arrow pointing in the direction of geometry, vector is its direction. Due to the vector it is able to describe the direction, the vector dot product:

$$\vec{u} \cdot \vec{v} = \|\vec{u}\| \|\vec{v}\| \cos\gamma \quad (7)$$

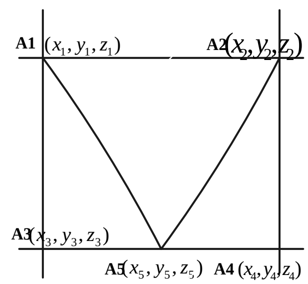

Fig.9 terrain meshes

You can get:

$$\cos\gamma = \frac{\vec{u}}{\|\vec{u}\|} \cdot \frac{\vec{v}}{\|\vec{v}\|} \quad (8)$$

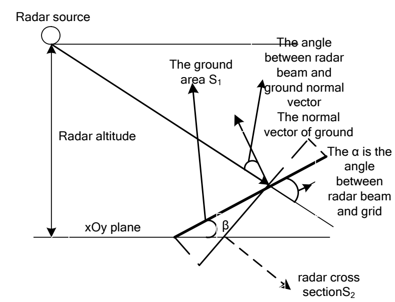

Fig.10 schematic diagram calculation of radar cross-section

Through the above two steps can be based on the DEM of the ground clutter power estimate formula:

$$P_r = \frac{P_t G_t A_r \sigma}{(4\pi R^2)^2} = \frac{P_t G_t A_r}{(4\pi R^2)^2} S_2 = \frac{P_t G_t A_r}{(4\pi R^2)^2} \cdot \frac{I^2}{\cos\beta} \cdot \cos\gamma \quad (9)$$

Atmospheric attenuation:
Spread effect mainly includes two aspects of atmospheric propagation attenuation and refraction phenomenon. With the increase of altitude, atmospheric attenuation reduced, thus, the actual radar transmission attenuation at work and the function of the radar range and target height.

The calculation method of radar range when considering communication:

If the waves are one-way propagation attenuation for δ dB/km, the radar receiver the received echo power density S3 and no attenuation based on the relationship between power densities S_3 is:

$$10\lg\frac{s'_3}{s_3} = 2\delta R \tag{10}$$

$$\lg\frac{s'_3}{s_3} = \frac{2\delta R}{10} \tag{11}$$

$$\ln\frac{s'_3}{s_3} = 2.3\frac{2\delta R}{10} = 0.46\delta R \tag{12}$$

$$\frac{s'_3}{s_3} = e^{0.46\delta R} \tag{13}$$

Based on DEM of ground clutter power estimate formula can be written as:

$$P_r = \frac{\mathrm{P_t G_t A_r}}{(4\pi R^2)^2}\cdot\frac{\mathrm{I}^2}{\cos\beta}\cdot\cos\gamma\cdot e^{-0.46\delta R} \tag{14}$$

4. Based on the DEM of the radar clutter simulation system

Based on the theory and method proposed in this paper, developed the radar clutter simulation software system based on DEM.

4.1 Design and implementation of the system

This system consists of two parts, the first part is the part 3 d terrain generation, and the second part is the radar ground clutter power calculation and display.

Radar power calculation formula, can know to calculate ground clutter power would have to know the normal vector of the ground, open when the generated terrain illumination has calculated the normal vector of the ground, can use at this time. Surface normal vector is obtained by computing the coordinates of three points, the normal vector on the ground, can according to the radar ground clutter power calculation formula to programming, and then get the three points of ground clutter power, so that you can get the whole terrain of the ground clutter power.

Get the whole terrain of the radar wave power, for the sake of the visual display on the screen. This system uses the images to display. The format of the picture I chose the BMP format.

In order to display the ground clutter power utilization picture, will be carried out on the ground clutter power processing, through the formula (15) corresponds to the range 0 ~ 255.

$$fa[i] = floor(255\frac{fa[i]-\min}{\max-\min}) \tag{15}$$

$fa[i]$ is the radar clutter power value, min is -100dBmw, max is A maximum of the ground clutter power value, $floor(x)$ remove the largest integer no greater than x.

System coordinate system for OpenGL used in calculation, this paper simulates 26.8km multiplied by the area of 26.8 km, radar uses the following several kinds of airborne radar.

Airborne radar hunter EC-153P: working frequency is I/J, peak power is 10Kw, the gain is 29.5dB, side lobe is -40 dB (300MHz), maximum distance is 150 km.

AN-APG-66 Fire control radar: working frequency is 9.7~9.9GHz, peak power is 20Kw,The antenna aperture is 0.78cm×0.78cm,the gain is 32dB, maximum distance is 148 km.

4.2 System simulation

In this paper, the radar's default location for the X direction from the origin is 9367.5m, Y direction is 4500m, Z direction is 6000m, and incident angle is 30°.

A. Select the same terrain choose different types of radar, fixed position and Angle carries on the simulation, the topography and roughness of terrain is set to 0.6,a random seed set to 600, as shown in Fig.11.

B. Choose different topographic choose same radar simulation, radar choose the AN-the APG-66 fire control radar, as shown in Fig.12.

C. Choose the same terrain, the same radar, different position, and different incident angles. The roughness of terrain set as 0.8, random seed set to 300, selected for the AN-APG- 66 radar fire control radar, as shown in Fig.13.

Through the graph you can see the same terrain, different radar land clutter image obtained is different also, and different terrain of ground clutter image is different also.

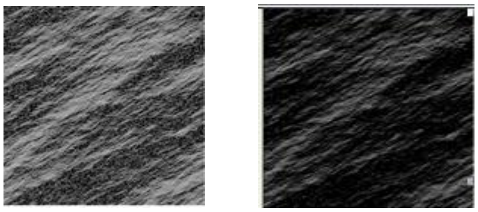

Fig.11 The image of radar ground clutter with the same terrain, terrain roughness 0.6 and random seed 600, the different types of radar, from top left: fire control radarAN-APG-66, airborne radar hunter the EC -153

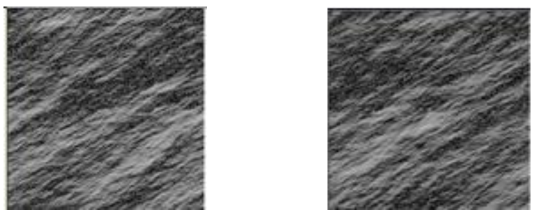

Fig.12 The image of radar ground clutter with the same types of radar, fire control radar AN-the APG-66, the different terrain, from top left: the terrain roughness 0.8 and random seed 300, the terrain roughness 0.8 and random seed 80

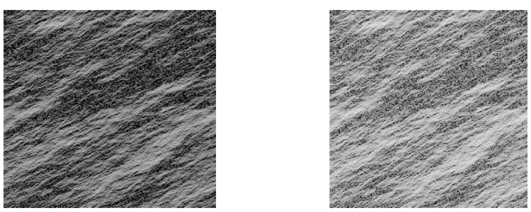

Fig.13 The image of radar ground clutter with the same types of radar and terrain, fire control radar AN-the APG-66, terrain roughness 0.8 and random seed 300, the different position and incident angles, from top left: the incident Angle to 45 °and X, Y, Z are the default values, the incident Angle to 45 °and X 3968.63 m, Y, Z are the default values

5. Conclusion

In the paper the simulation of ground clutter based on DEM is researched. It is studies how to use fractal arithmetic to produce random digital elevation. Based on DEM, terrain is divided into many simple grid surfaces. This geometry is constituted by four adjacent high points of the terrain. It is detailed to discuss how to account the power of each unit ground clutter by using radar equation and digital elevation, use the superposition principle to superpose each unit power, and then achieve the ground clutter of entire ground. The entire power of ground clutter wave is got in to unitary processing, correspond it to 0~255 grey level. Through the BMP picture's read-write, the grey level which will obtain was written in the BMP file in order to realize showing of the entire power of ground clutter. The results show that it is fit for what the project needs.

Acknowledgments

National natural science foundation of china, 5097017.
Central university basic research foundation, HEUCF041326.

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