Research of Visual Multi-medium* Geography Information System (GIS)

Chen Baowen Liu Shulou** Liu Xiaodong***

(Commission for Integrated Survey of Natural Resources,
The Chinese Academy of Sciences, Beijing 100101, China)

ABSTRACT

This paper will introduce the structure and user interface design of Visual Multi-Medium GIS what we researched, theories and methods of geography reality graph, including the 3- D modeling design of terrain and geomorphologic, veins processing of the earth's surface , illumination model, color model of surface feature, shade processing and methods of surface features covering.

1.I INTRODUCTION

With the great advances and development at full speed on computer technology and geography research, inquires of people are quite wide and urgent to automatically management and research on resources. As a tool of this demand, GIS is followed with the more and more interest, the scope of its application has been increased rapidly. However, because of the appearance of multi- medium technology and the demand of inquiring high-speed for GIS, the research of visual multi-medium GIS has become an important focus of our time on GIS research. Visual multi-medium GIS is to use graph, or image , word, sound etc. multi -medium to express information and research results in GIS. Common saying : a graph surpass thousand words. This the kind of GIS has a very nice effect for the use and scientific research. The Visual Multi-Medium GIS is built on the base that we have finished "COMPUTER GEOGRAPHY REALITY GRAPH SIMULATION SYSTEM " has a good reality effect and to convenient for user. The research focus of this system is how to use multi-medium technology, to research and to establish methods of reality graph to make system visualization and flexibility of intersection and with synthetically expressing ability. Up to now, we have solved successfully these problems and two sets of national GIS systems have been established on SUN and SGI workstation. Owing to the words limitation, only two difficult points will be introduced in my article. They are as follows:

* SYSTEM STRUCTURE AND USER INTERFACE DESIGN.
* THEORY AND METHODS OF GEOGRAPHY REALITY GRAPH

1. System structure and user interface design.

1.1 System structure design

This system is an open one which faces user and is convenient for the development second time and focuses on the extension and operation of its level in the system structure design. The system structure is divided into three levels:

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** Institute of Geography , Chinese Academy of Sciences

*** State Standard Press, Bureau of Technology Supervision of China

1.2. User interface design and intersection communication

The production of main interface and each level interface ;
User interface design is completed on the basis of data structure.
The user interface data structures had designed in 1.1. Through . Through
operating the structure, we can get each level user interface. For example, production of the main interface like this:

```
structMenu mainmenu = { " ",8,0,0,0,0,{
                "file management"
                " data process"
                " production graph"
                " edit graph"
                " base management"
                " screen management"
                " system display"
                " return",0,0};
```

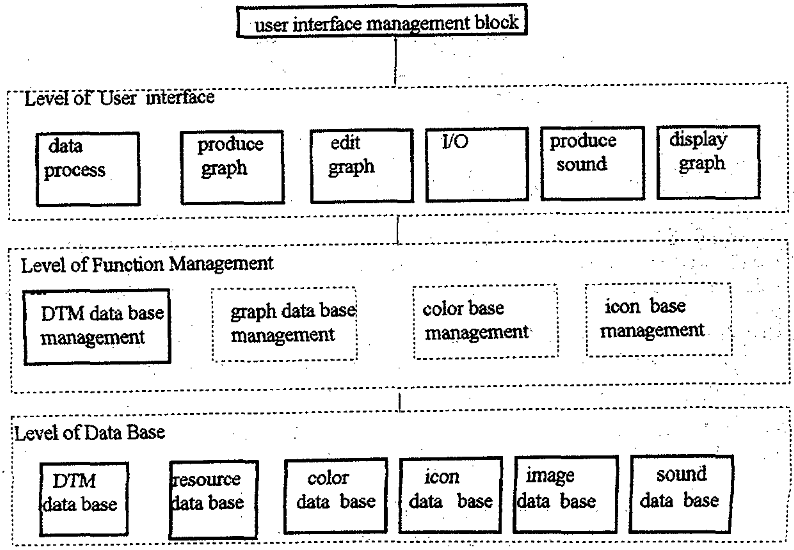
then, call function pop() to make it be displayed on screen .
As for intersection communication, it is to use a selection function and function treating function to be completed. Therefore, the a lot of intersection communications and functions are finished on the basis of a lot of function functions and structure operation carried out. For example , figure 2.

System intersection interface 2.1.

System intersection interface 2.2.

System intersection interface 2.3.
(Visual Multi-Medium relic system,
Baoding region of Hebei province)

Figure 1. Scheme of System Strcture



2. Methodology of Visualized Graphics

Visualized graphics is an important branch of computer graphics. It is a new technology about production visualized graphics with continuous tone, just as photograph, on graphic equipment of computer, by the theories and methods of mathematics, physics, optics, chromatics, physiology and computer technology, etc. As one of the three critical technologies of contemporary high technologies (visualized graphics, multiple media, parallel processing), Visualized graphics has board prospect and is noticed extensively.

The main methods of production of visualized graphics can be induced to the following three topics:

* design of geometric figures with 3-D sense of reality: in the research of visualized multiple media GIS, we mainly discuss models for 3-D visualized figures of topography and landscape, e.g. construction of DTM, processing of surface texture and the overlay of objects.
* transformation of projection: transformation of projection from 3-D to 2-D plate, and display stereoscopic graphics on 2-D plate.
* removal of hidden faces: clean graph and make the graph with real visual effect.
* processing of light and color: simulate the true brightness and color of the visible faces of objects to enhance the stereoscopic and reality senses.

This article will only introduce some methods for the above topics.

2.1 3-D geometric graph of topography and landscape

2.1.1 Methods for construction of DTM

Since the sample points of altitude are dispersed and distributed randomly, the altitude of arbitrary point can not be got directly, but only through some dependable algorithms with the altitude data of known sample points. We hereby give an algorithm called "weight average with double linear interpolation" (Figure 3.)

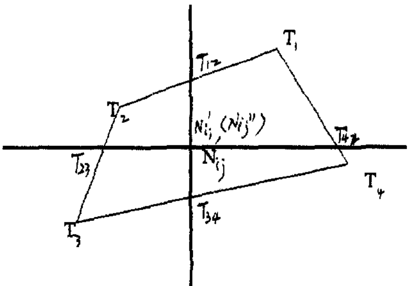


Fig. 3 . Algorithm of DTM producing

Given grid node $N_{ij}(x_{ij}, y_{ij}, z_{ij})$, x_{ij}, y_{ij} are known but z_{ij} is unknown, after the scene to be described is grated. Building up Cartesian coordinate system with N_{ij} as origin, and seating for the four nearest points to N_{ij}, we can then calculate z_{ij} from the altitude of the four sample points. The detailed algorithm is:

Given T_i (i= 1, 2, ..., n) as sample points and T_1 ,T_2 ,T_3 ,T_4 are the four nearest points to N_{ij} . T_{41} ,T_{12} ,T_{23} ,T_{34} are the intersect points T_4T_1 ,T_1T_2 ,T_2T_3 ,T_3T_4 coordinate axes respectively. If the altitude of T_{41} is H_{41}, then:

H41 = H4 + (H1-H4)(Y41-Y4)/(Y1-Y4) .... (2.1.1-1)
H12 = H1 + (H2-H1)(X12-X1)/(X2-X1) .... (2.1.1-2)

The algorithm of H23,Hij', are the same as that of H_{41}

The algoriyhm of H34,Hij', are the same as that of H12

So, $Hij = (Hij' + Hij'') / 2$ ....(2.1.1-3)

With the above algorithm, the altitude of every of node the grid will be got. Let the node be T_{ij} (i= 1, 2, ..., m, j=1, 2, ..., n), then the matrix T (2.1.1-3) is the DTM of the described scene.

$$T = \begin{vmatrix} T11 \; T12 \ldots\ldots T1n \\ T21 \; T22 \ldots\ldots T2n \\ \ldots\ldots T3n \\ \ldots\ldots \\ \ldots\ldots \\ Tm1 \ldots\ldots Tmn \end{vmatrix} \quad \ldots\ldots(2.1.1\text{-}4)$$

2.1.2 Processing of surface Vein

Because of different scale of visualized graphics, more exquisite processing of figures on the basis of DTM is necessary. It is called processing of texture. It becomes more important when micro-landscape simulated. We hereby use Fractal Brownian Motion (FBM) method, which is suitable for texture processing and for design of 3-D geometric figures as well.

The FBM method is described as following:

$u \in (-\infty, +\infty)$, : real,

$w \in W$, W: sample space, w: sample point

Brown Motion is a random procession. Its description function can be defined as a real random function B(u,w). The function has the following characters:

Its increment, $B(u_2,w)-B(u_1,w)$, is normal distribution with the average of 0 and variance of $(u_2 - u_1)$; and when (u_1, u_2) and (u_3, u_4) are not identical, $B(u_2,w)-B(u_1,w)$ and $B(u_3,w)-B(u_4,w)$ are independent to each other. Given h as a variance and $0 \le h \le 1$, and b_0 is a real, then the FBM of with variance as h and initial value as b_0 is:

$B_h(o,w) = b_0$

$$Bh(u,w) - Bh(0,w) = 1 / \Gamma(h+0.5) * \{ \int [(u - s)h-1/2 - (-s)h-1/2] dB(S,W) + \int (U-S)h-1/2dB(S,W) \} \quad \ldots\ldots (2.1.2\text{-}1)$$

When h=0.5, $B_h(u,w)$ is normal Brownian Motion. It is easy to find that the first character of FBM is its self similarity, i.e. when $B_h(u+t\Delta u,w)-B_h(u,w)$ is enlarged with t^{-h} times, the increment of $B_h(u + \Delta u,w)-B_h(u,w)$ and the increment of $B_h(u+ \Delta u,w)-B_h(u,w)$ has same distribution; and h is called coefficient of self similarity.

The second character of FBM is that its conditional exception can be gotten from the following quation:

Given $B_h(o,w) = 0$, then

$E[Bh(ku,w) | Bh(u,w)] / B(u,w) = 0.5(k + 1- |k-1|$ ....(2.1.2-2)

When k=0.5, then

$E[Bh(u/2,w) | Bh(u,w)] = 0.5Bh(u,w)$

$Bh(0,w) = 0$ ....(2.1.2-2)

It is not easy to make exquisite image with the FBM method. We then can adopt the method of a projection approximate FBM.

Given that the random function F(e,u) returns a random variable with average as e and variance as u, in order to make a fractal line between two points, the middle point of the line linking the two end points moves round along the normal axis and the random variable F=F(e,u) can be produced.. Its average, e, can be arithmetic average of the values of random variable of the two end points, (given as f_1 and f_2); while the variance, u, can be constant; then the FBM of the middle point will be got from the following equation:

$Fm = F((f1+f2)/2 , 2u(f1+f2)/2+F(0, 2u)$ ....(2.1.2-4)

In the above equation, m is the order of exquisite processing. Therefore, when u is decided, we use h to control the degree of self similarity, i.e. to control the exquisite degree of the produced images. A big h leads to very exquisite one while a small h produces rough vein.

When we use the above method to carry out exquisite processing on topographic surface described with DTM, because of the self similarity of FBM, the details on the new segments are similar to the results of previous processing and the total degree of irregularity of the outline and details are identical, therefore, the visualized graphics produced with this method owns very good visual effects.

2.2 Projection transformation

Because monitor and plotter can only present images on 2-D space, we have to reduce the order of dimension with the help of projection in order to present 3-D images. We have used three kinds of projection system to cope with the needs of different processing.

2.2.1 Prospective projection

Prospective projection is to observe an object comes from vision point, and the intersects between the vision lines and the projection plate build up the projection of the object. Because the projection of a straight line in 3-D space is still straight line, we need only to find the projection of the two end points of the line and link them in order to get the projection of the original line.
Given the vision point $C(x_c, y_c, z_c)$ and that the projection on the plate of $z=0$ of an arbitrary point in the space $A(x,y,z)$ is (x_p, y_p), we get the following equations according to the similarity transformation:

$$Xp = Xc + (X - Xc)*Zc / (Zc - Z)$$
$$Yp = Yc + (Y - Yc)*Zc / (Zc - Z) \quad \text{.....................................} \quad (2.2.1\text{-}1)$$

2.2.2 Parallel projection

If the vision point is moved to point infinite far away, the vision lines from the vision point to an object become parallel lines. Then the projection of the object on vision plate is called parallel projection. Parallel projection requires the direction of the projection, i.e. the vector of (x_d, y_d, z_d).
Given an arbitrary point $A(x,y,z)$ in 3-D space, its parallel projection on plate of $z=0$ is (x_p, y_p), The similarity transformation is:

$$Xp = X - Xd * Z / Zd$$
$$Yp = Y - Yd * Z / Zd \quad \text{..} (2.2.2\text{-}1)$$

2.3 Illumination model and brightness processing

Besides stereo figure and surface texture simulation, processing of illumination, color and brightness is the important factors of simulation of visual effects. There are a lot of methods for these processing. Because of the size of this article, we hereby only introduce some main methods.
Illumination processing contains processing of point light source, plate light source and radiation strength of multiple sources. Since we are mainly dealing with the simulation of solar light and main illumination impact of natural landscape, we omit the impact of environment light and only use the algorithm for processing of point light source. Phong's Model has described the algorithm quite well.
Phong's illumination model is described as following:
The model takes account for human visual impacts of three part of lights:

a.) light reflecting from the surface of an object, i.e. reflection light;
b.) light transmitting an object and radiating from another end, i.e. transmission light;
c.) reflecting light from environment lights.

Only the reflection light can get into human visual sense. It is combined with three parts, i.e. reflection light from environment objects, diffuse reflection and mirror reflection. The sum of the three parts is the core part that Model takes account for.
The strength of lights will produce different color and brightness in human visual sense. What the model takes account for is the amount of energy accepted by visual sense. The construction of the model is following:

* user interface level * function model-block level * data base level (find figure 1.)
According to this level system structure , system control , data current ,
its data structure can be classified into four main types.

a) Data structure of user interface:
The system data structure what we designed is completely suitable to every level interface design. It is as follows:

```
struct menu{
char menu-name[];              /* the name of interface */
int item-nu;                   /* the total number of interface */
int o-x,0-y,w,h;               /* the original situation of interface,
                                  width, height */
char item [] [];               /* memory space of interface signal
                                  information */
struct pixrect *rect, *mrect;  /* system support software of producing
                                  button graph interface */
};
```

b) Data structure of intersection communication:
This structure is suitable to all dialogue intersection communication situation.

```
struct talkbox{
char tb-name[]
int num;
int o-x,0-y,w,h;
char prompt[] [];       /* intersection prompting information */
char answer[] []        /* answer information memory space */
};
```

c) Intersection communication structure of data base:

```
struct cmap
{
int type;
int nbytes;
char *data;
};
```

d) function call and information state data structure:
The structure is to be used to random calls.

```
struct state {
int flag;
int cover-mode;          /* produce the type of reality graph */
char prj-dir[]           /* set up projection transformation */
char orent-x[20] orenty[20];
char dtm file[20]
int row,lol;
int seg-num;
int *heiseg;
float *slopseg;
int *area;
int image-num;
char image-name[][];
};
```

* diffusive reflection light: according to the optical theory, the brightness of reflected light on a diffusive reflection surface is direct proportion with the cosine of the incident angle (the angle between incident light and the normal vector of the surface), i.e.

$$I_1 = I_{pd} \cos i \quad \text{.................................(2.4-1)}$$

I_1 : brightness of reflected light
I_{pd} : the strength of reflected light when the incident light is perpendicular to the surface
i : incident angle

* brightness of mirror reflection light:

$$I_2 = I_{ps} \cos^n \theta \quad \text{................................(2.4 –2)}$$

I_{ps} : brightness of mirror reflection light
θ : incident angle
n : concentrating coefficient of mirror reflection light
I_2 : brightness of mirror reflection light accepted by observer

* light from environment reflection: It depends on the described object. We take it as a constant, I_3, since we mainly describe topography, vegetation and landscape.

So, the brightness accepted by vision, I, is:

$$\begin{aligned} I &= k_a I_1 + k_d I_2 + k_s I3 \quad \text{.............................(2.4-3)} \\ &= k_a I_1 + k_d I_{pd} \cos i + k_s I_{ps} \cos^n \theta \end{aligned}$$

k_a , k_d , k_s are proportional coefficient of the three kinds of lights in the total reflections.
After we sum up all specific sources:

$$I = k_a I_1 + \Sigma (k_d I_{pd} \cos i + k_s I_{ps} \cos^n \theta) \quad \text{...........(2.4 –4)}$$

Then we got a practical Phong's Model.
According to the relationship between spectrum and the three primary colors accepted by vision, we can get the R, G, B values of each part of the lights. Finally, R, G, B values of the vision accepted colors are:

$$\begin{vmatrix} R \\ G \\ B \end{vmatrix} = ka \begin{vmatrix} r3 \\ g3 \\ b3 \end{vmatrix} + \Sigma(kd \begin{vmatrix} rpd \\ gpd \\ bpd \end{vmatrix} \cos i + ks \begin{vmatrix} rps \\ gps \\ bps \end{vmatrix} \cos \theta \quad \text{....(2.4-5)}$$

2.5 Processing of voice

Firstly, we record simulated signals of voice with recording equipment, then we carry out digital sampling on the signals with the multiple media resources in SUN workstation, and save the data in wave format, so we accomplish the dubbing of graphics, images and literature.

3 Concluding remarks

Visual multiple media GIS is developed from the integration of multiple media technology and geographic simulation technology. Both of the two fields are still developing parallel. At present, the most important contribution of multiple media is that it has improved the interface of human and machine. In the future, it may equip computer with visual, oral and aural capabilities and produce deep effects on the mechanism and system structure of computers. Simulation technology of geographic visualized graphics is born with the development and application of computer graphics. Using geographic simulation technology to process remotely sensed images will have important impact on the development of pattern recognition. It have produced very good effects on simulation of micro-landscape, and composition of natural scene. This kind of technology can be further developed for ecological design, environmental monitoring, and environmental change researches; and it can make GIS more practical.