Three Dimentional Display of Aerial Photographs[*]

DAN Hanbin[①], WU Lun[②], CHENG Jicheng[③]

PURPOSE:

This paper presents a fast and efficient method for perspective transformation. A technique that uses photographs and DEM for a three-dimensional representation of the scene is discussed. This technique needn't to match the image and DEM together. The resulted/scene is rather valid.

KEY WORDS: DEM, Visibility, Aerophoto 3-D Display

1. Outline

The basic idea to form the landscape map by using computer is to use computer to emulate the image-producing process of an ideal camera. That is to rebuild the three-dimensional aimed region with a computer to emulate a focus-changeable ideal camera which has been placed at some location in the space after the landform surface has been defined by a digital altitude network which is stored by grid form. The basic process is: A. to change the aimed region and project it into a visual system; B. To emulate or match the corresponding landscape; C. The discernment to surface visibility.

Because the whole process is digital and completed by computer, it is very easy to adjust the focus point and focal distance after the visual point has been changed, and it is able to form a landscape at any angle and in any size.

2. Projection Transformation

As shown in Fig. 1, it is supposed that the sptial coordinate system of material object is $\theta_w - X_w Y_w Z_w$, the coordinate system of visual system is $\theta_e - X_e Y_e Z_e$ and the spherical coordinates of the ideal camera in $\theta_w - X_w Y_w Z_w$ are (θ, φ, dd). So their corresponding spatial three dimensional coordinates are (a, b, c) and the focus of the camera is located at point (a', b', c')
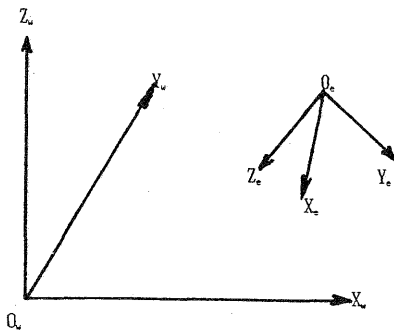
It is supposed that the coordinates of a point wherever in the aimed region in the spatial coordinate system of material object are (X_w, Y_w, Z_w)

The corresponding homogeneous coordinates are $[X_w, Y_w, Z_w, 1]$;

The coordinates of this point in the coordinate system of the visual system are (X_e, Y_e, Z_e) and the corresponding homogeneous coordinates are $[X_e, Y_e, Z_e, 1]$.

After a series of translation, rotation and transformation, their relationship is

$$[X_e, Y_e, Z_e, 1] = [X_w, Y_w, Z_w, 1] \cdot V$$

In the above equation, V is a 4×4 matrix,

$$V = \begin{bmatrix} T_{11} & T_{12} & T_{13} & T_{14} \\ T_{21} & T_{22} & T_{23} & T_{24} \\ T_{31} & T_{32} & T_{33} & T_{34} \\ T_{41} & T_{42} & T_{43} & T_{44} \end{bmatrix}$$

$$T_{ij} = f_{ij}(a, b, c, a', b', c',), \quad (i, j = 1, 2, 3, 4)$$

Supposing the plane coordinates in the visual system are (Xs, Ys), then:

$$Xs = f\frac{Xe}{Ze}, \quad Ys = f\frac{Ye}{Ze}, \quad (f \text{ is the focus of the camera})$$

The projection transformation is carried out according to the above formulas.

3. Emulating and Matching the Corresponding Images

The images in the landscape map can be gained by drawing from matching the image data base.

3.1 Image Emulation

It is supposed that digitized landform surface is in grid form.

Zoo is the point which needs to be emulated, the other points are eight points in the neighboring area of Zoo. (As shown in Fig. 2)
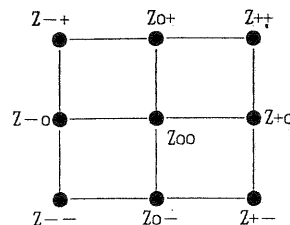

Fig. 1 The relationship between the spatial coordinate system of material object and the coordinate system of visual system

Fig. 2 The Map of Relationship among DEM Nodes

Supposing the gradient of the ground surface at point Zoo is P (along X-axis) and q (along Y-axis), then:

$$p=[(Z_{++}+2Z_{+0}+Z_{+-})-(Z_{-+}+2Z_{-0}+Z_{--})]/(8\Delta x)$$
$$q=[(Z_{++}+2Z_{0+}+Z_{-+})-(Z_{+-}+2Z_{0-}+Z_{--})]/(8\Delta y)$$

In above equations, Δx, Δy are the sizes of the image which needs to be emulated.

Supposing the position vector of the sun are $(-p_s, -q_s, 1)$ and

$$p_s=-\cos\theta d \cdot ctg\theta h, \quad q_s=-\sin\theta d \cdot ctg\theta h$$

θh, θd are the azimuth angle and the altitude angle respectively, then, the brightness value of point Zoo is:

$$I(x,y)=p \cdot \frac{(1+p \cdot p_s+q \cdot q_s)}{\sqrt{1+p^2+q^2} \cdot \sqrt{1+p_s^2+q_s^2}}$$

According to the corresponding satelite photographs or the aerial photographs, we can obtain fairly real images.

3.2 Matching the Corresponding Images

When we have stored the image date base, we can look for a kind of registration algerith   speed. Further more, the landscape map can reflect the present situation wholly. Because we can gain the digital images from satellite or aviation very quickly from a lot of sources, the landscape map of aerial region can be displayed quickly after the computer receives the images.

Using the above-mentioned methods of emulating the images to emulate the images in the aimed region and then matching with the image data base, we can get a range which is somewhat bigger than the aimed region. Then, according to a few of characteristic points, we can set up the accurate relationship between a landscape point and its image:

$$I=F_i(x,y,z,\theta_1,\theta_2,\cdots\cdots\theta_6);$$
$$J=F_j(x,y,z,\theta_1,\theta_2,\cdots\cdots\theta_6);$$

In above equations, (x,y,z) are the coordinates of the landscape point in the sptial coordinate system of material object, $(\theta_1,\theta_2,\cdots\cdots\theta_6)$ are six control parameters of the digifal image in the matched scope. They can be solved from the characteristic points. And the images in the landscape map can be determined according to the above-mentioned relationship.
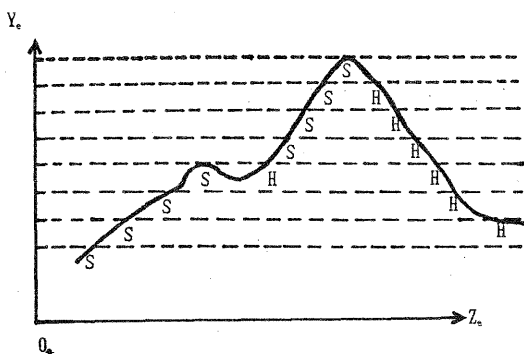

Fig. 3   Chart of discernment to surface visibility

4. Discernment to Surface Visibility

In order to be brief, we use a polar coordinate section at some degree to expound the problem of discernment to surface visibility.

When the computer is producing the landscape map of the aimed region, it needs to decide which area needs to be displayed and which area doesn't need to be displayed. And that is the problem of discerament of surface visibility. (Fig. 3)

As the above figure shows, after the aimed region has been transformed from the spatial coordinate system of material subject to the coordinate system of visual system, values of coordinats y of a section in the coordinate system of visual system determined its surface visibility.

Along y axis of coordinates to draw isochores parellel to z axis of coordinates, these parallel lines intersect the section. When there is only one intersection point, the point is visible; when there are more then one intersection point, their least value of coordinates z is visible but the other ones are invisible. As the Figure 3 shows, "S" are the visible points and "H" are the invisible points.

Before the landscape map is exported, it should be appropriately adjusted and smoothed. The detailed methods are not expounded here.

5. Flow Chart and Effects

According to the above-mentioned methods and considering the ability of DOS operating system to manage the inner storage, we handle the aimed region in divided parts with block software writen in Microsoft C language. Although the speed is somewhat slower, the size of the aimed region won't be limited. The flow chart of software algorithm shows as Fig. 4.
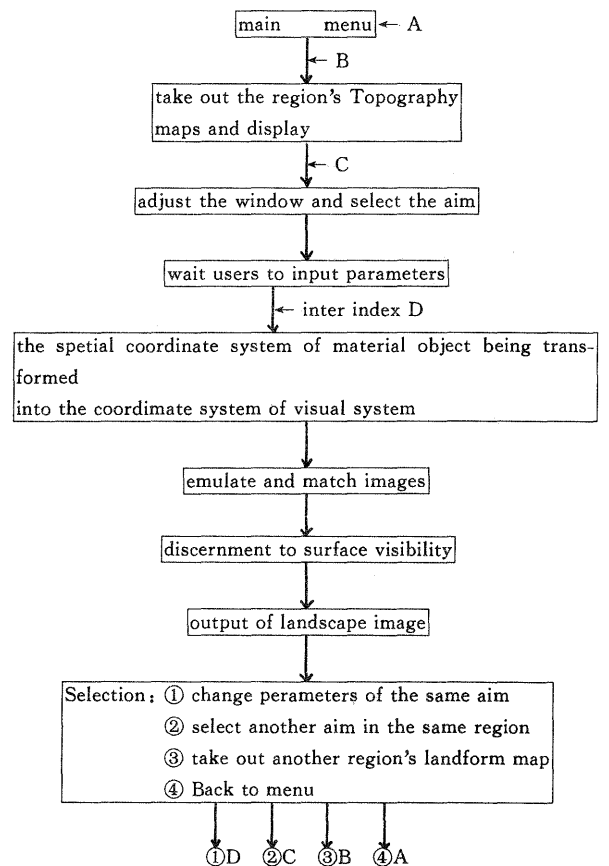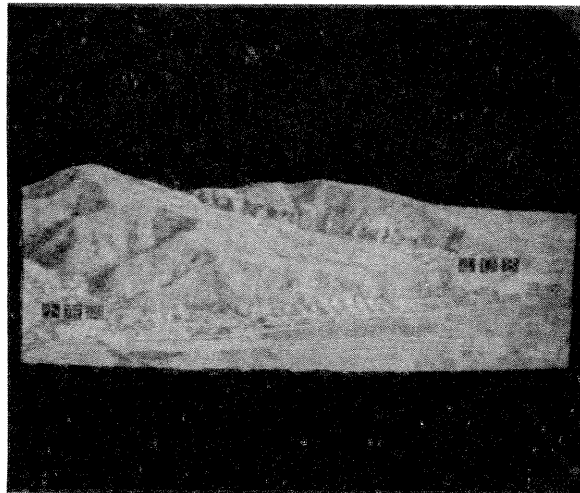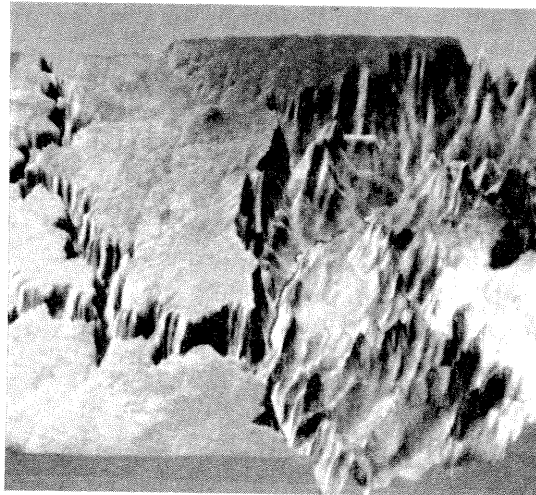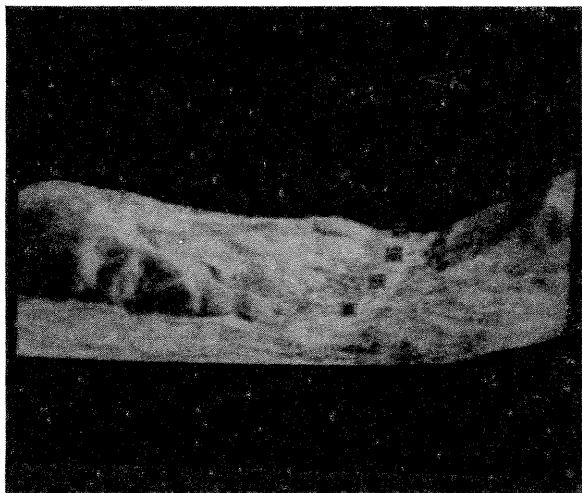

Fig. 4   Flow chart of software Algorithm

$$\frac{1 \mid 2}{3 \mid 4}$$

Explanations for Plates

Plate 1-3.   Examples of Three-D display of aero-photoes of some regions in North China.

Plate 4.   Example of Three-D display of Landsat image of the Colorado canyon.