

STUDY ON OVERLAYING REMOTE SENSING IMAGE ON SURFACE-UNDERGROUND CONTRAST PLAN

S. J. Mao^a*, S. L. Peng^a, J. Z. Chen^b, M. Li^a

^aInstitute of Remote Sensing and Geographic Information System, Beijing 100871, P. R. China - sjmao@pku.edu.cn

^bSchool of Resource and Safety Engineering, China University of Mining & Technology, Beijing 100083, P. R. China - jingzhuchenchen@gmail.com

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ABSTRACT:

Surface-underground contrast plan, as one of the most important engineering maps in the general safety management and production of the coalmine, overlays both topographical map and underground mining engineering plan together, and means to describe the mining area, underground roadway layout, location of working face, rock movement, hydrological distribution, the impact of excavation on the environment and much else during the mining process. Also, the surface-underground contrast plan is a vital evidence for work safety supervision and management department to judge whether the mining activities belong to cross-border mining or unlawful mining or not. However, the data acquisition of terrain on surface-underground contrast plan is very laborious and generally cannot be finished in a short time. Surface changes cannot be embodied on the contrast map in time. In order to solve these problems, a new type surface-underground contrast plan is presented in this paper, in which high resolution RS image replaces the tradition topographical map. After registered by the mining engineering plan, RS image and vector map is fused with each other and provide the richer information on the surface of mining area. The paper mainly concerned about the key techniques and algorithm implementation. Several algorithms was studied and accomplished, including image coordinate transformation, surface spline function calibration, massive image display and characteristic feature highlighted display technique. Programming and testifying have been done. The algorithms were testified by Getting mine, Jining Mining Group, Shandong Province. The results proved that those algorithms are simple and novel for users.

1. INTRODUCTION

As one of the important maps of the mine production, the traditional surface-underground contrast plan is made up of mining engineering plan and the topographical map. The overlay of the two kinds of map can show mining area, laneway position, working face, rock movement, surface subsidence, hydrology condition, the environment influence caused by the mining, etc. The surface-underground contrast plan is a vital evidence for work safety supervision and management department to judge whether the mining activities belong to cross-border mining or unlawful mining or not. However, surface-underground contrast plan is updated slowly. It can not show the changes of the environment in time.

This paper presents a new kind of new type surface-underground contrast plan which integrate raster remote sensing image with vector engineering map. High resolution remote sensing image, which is multi-temporal multi-band data source, can supply abundant truthful spatial information. The new plan integrating the advantages of vector and raster provide not only real information, but also display the information of dynamic changes realistically. Meanwhile, the surface-underground contrast plan is easier to update, because the change of surface information can be adjusted by new remote sensing image, not redrawing or remapping.

2. WORKFLOW OF OVERLAYING RS IMAGE WITH VECTOR MAP

According to the requirements of safety production in coal mine, the author designs and develops a new overlay function based on Longruan GIS. Longruan GIS is a professional GIS developed from the bottom layer in the windows environment. The system aims to help engineers to manage coal mine geological and surveying spatial data. It has functions of CAD and GIS function both. The research object of this paper is to implement key overlay techniques on the Longruan GIS, including image correction, coordinate transfer, image re-sampling, image display, and highlight display, etc.

There are 4 steps in the work flow as shown in figure 1. The process of overlaying remote sensing image is divided into 4 steps: image pre-treatment, image calibration, display of vector and raster image and characteristic feature display.

1. Image pre-treatment. It includes the enhancement of the contrast gradient and the edge of the image, and the coordinate conversion from UTM-WGS84 to Beijing54 or Xi'an80 system. Image fusion fuses high resolution panchromatic image with multi-spectral image. The fused image possesses high resolution and the information of colors in the same time.

2. Image calibration. There are two kinds of calibration. The coarse calibration is used to display as signal map with low

* Corresponding author. sjmao@pku.edu.cn; phone: +8610 6275 9803;

accuracy, and the accurate calibration, by re-sampling the homonymy points to obtain the image with accurate information.

3. Image display. Virtual memory technology and memory mapping are used to display continuously the whole mass image.

4. Spatial feature enhancement. The system can project the partial features user concern as entities. Entities keep the size and relative location, to make it is easy to obtain the visual information needed.

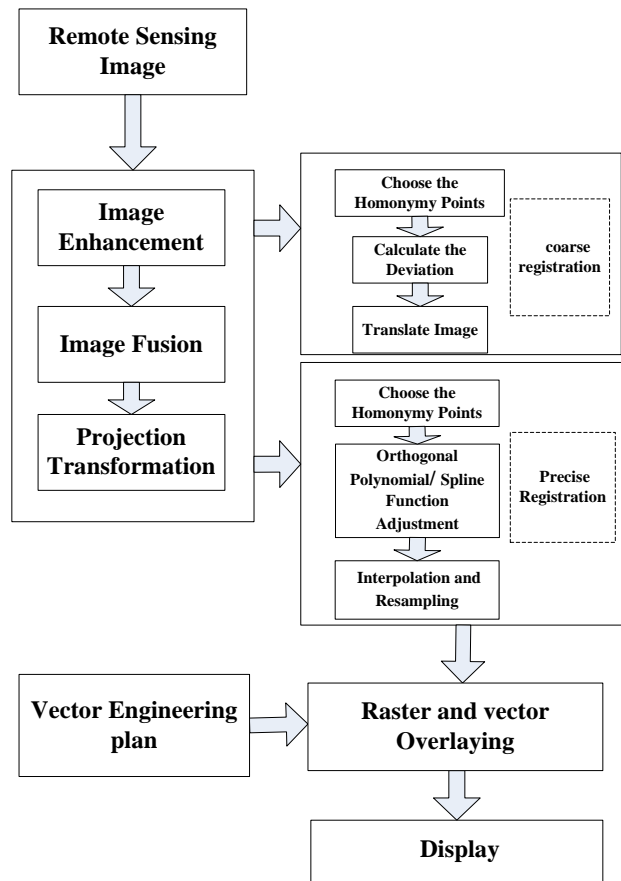


Figure 1. The schematic diagram of the overlay of RS image and the vector mining diagram

3. KEY TECHNOLOGY

This paper expatiates on 4 techniques below as the keystone.

3.1 RS image projection and conversion

The RS image coordinate system is UTM WGS84 coordinate system, which needs to convert to Beijing54 or Xi'an80 coordinate system, so that RS Image could be used in LongruanGIS platform, and implement registration of vector map of mines. Conversion to Beijing 54 system as an example below, the main steps are:

1. According to the ellipsoid parameter of WGS-84, $(B_{84}, L_{84}, h_{84})^T$ can be converted to $(X, Y, Z)^T$, which is the rectangular space coordinate, by the formulas (1):

$$\begin{cases} X = (N + h) \cos B \cos L \\ Y = (N + h) \cos B \sin L \\ Z = [N(1 - e^2) + h] \sin B \end{cases} \quad (1)$$

where

$$N = \frac{a}{\sqrt{1 - e^2 \sin^2 B}}$$

2. According to the ellipsoid parameter of Beijing 54, $(X, Y, Z)^T$ can be translated to geodetic coordinate $(B_{54}, L_{54}, h_{54})^T$ in formulas (2):

$$\begin{cases} L = \arctan(Y / X) \\ B = \arctan[(Z + Ne^2 \sin B) / \sqrt{X^2 + Y^2}] \\ H = \sqrt{X^2 + Y^2} \sec B - N \end{cases} \quad (2)$$

3. We should know the central meridian line, elevation of projection surface and the amount of translation from north to east, and translate $(B_{54}, L_{54})^T$ to Gauss coordinates $(x'_g, y'_g)^T$. The steps above are finished on the assumption that WGS-84 and Beijing 54 system use the same axes of the ellipses. In the practical applications, we need consider rotation, translation and scaling. Given that part of the chosen control points' coordinates are known as $(x_g, y_g)^T$, we can interpret the relationship of plane coordinates $(x'_g, y'_g)^T$ and $(x_g, y_g)^T$ as below:

$$\begin{pmatrix} x'_g \\ y'_g \end{pmatrix} = \begin{pmatrix} x_0 \\ y_0 \end{pmatrix} + (1 + r)R(\theta) \begin{pmatrix} x'_g \\ y'_g \end{pmatrix} \quad (3)$$

where

$(x_0, y_0)^T$: The amount of translation

r : The scale of scaling

$R(\theta) = \begin{pmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{pmatrix}$: Matrix of rotation

θ : rotation angle.

In order to obtain the parameters in (3), two points are needed at least. Supposed we obtain a large number of control points, the least square method can be used to get optimal parameters' value by fitting the curved surface. The whole image conversion can be done according to the parameters obtained above. However, model (3) is linear while Gauss projection whose one degree term is proportional to y_g^2 is nonlinear, so the plane translation model is only used in small scale projects. For large ones, spatial projection translation model is needed.

3.2 The surface spline function for image calibration

After the correction in the RS image, the precise calibration can be done by chosen homonymy points in the image. The familiar ways are common polynomial correction, orthogonal polynomial correction, surface spline correction, etc. in this paper, we pose a different calibration method which the correct

process is based on the vector mining engineering plan, not the image. The vector map is made by geographic surveying which is more precise than image.

Image calibration is to choose a serial of corresponding points $[(x_i, y_i), (X_i, Y_i), i = 0, 1 \dots n - 1]$ from the reference image and the corrected image. (x_i, y_i) means reference points, and (X_i, Y_i) is corresponding point of the corrected image. The task is to find the functions $f()$ and $g()$ to correct the image, by using the relation of the two serials of points. Once $X_i = f(x_i, y_i), Y_i = g(x_i, y_i)$ is gotten, the corrected points' value of coordinates could be calculated.

The way of surface spline function is introduced in this paper. The reason of smoothing of the spline surfaces and spline curves lies in their first order continuous and second order first order continuous. In geologic field, surface spline function is a relatively successful way for interpolation (Goshtasby, A., 1988). The advantages are: the origin data needn't be ranged to a regular matrix and it can get any order differentiable smooth surface only by the boundary information without the derivatives. If the surface spline function can be regarded as the distortion of blending a limitless plane, it can be expressed below as formula (4):

$$z = a_0 + a_1x + a_2y + \sum_{i=1}^n F_i r_i^2 \ln(r_i^2) \quad (4)$$

$$r_i^2 = (x - x_i)^2 + (y - y_i)^2 \quad (5)$$

where

a_0, a_1, a_2, F_i : the coefficients of the surface spline function;

i : the number of the original points, $i=0, 2, \dots, n-1$.

The coefficients can be calculated by the equations below:

$$\begin{cases} z_i = a_0 + a_1x + a_2y + \sum_{i=1}^n F_i r_i^2 \ln(r_i^2) \\ \sum_{i=1}^n F_i = \sum_{i=1}^n x_i F_i = \sum_{i=1}^n y_i F_i = 0, \\ r_i^2 = (x - x_i)^2 + (y - y_i)^2, \end{cases} \quad (6)$$

In equations (4), if X instead of z in the surface distortion, we can get the equations translate the image which wait for correcting from the image coordinates to the actual coordinates. Expressing as matrix is:

$$AX = B \quad (7)$$

where $X = [F_1 \ F_2 \ \dots \ F_n \ a_0 \ a_1 \ a_2]^T$
 $B = [X_1 \ X_2 \ \dots \ X_n \ 0 \ 0 \ 0]^T$

$$A = \begin{bmatrix} r_{0,0}^2 \ln(r_{0,0}^2) & \dots & r_{0,n-1}^2 \ln(r_{0,n-1}^2) & 1 & x_0 & y_0 \\ r_{1,0}^2 \ln(r_{1,0}^2) & \dots & r_{1,n-1}^2 \ln(r_{1,n-1}^2) & 1 & x_1 & y_1 \\ \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ r_{n-2,n-1}^2 \ln(r_{n-2,n-1}^2) & \dots & r_{n-2,n-1}^2 \ln(r_{n-2,n-1}^2) & 1 & x_{n-2} & y_{n-2} \\ r_{n-1,0}^2 \ln(r_{n-1,0}^2) & \dots & r_{n-1,n-1}^2 \ln(r_{n-1,n-1}^2) & 1 & x_{n-1} & y_{n-1} \\ 1 & \dots & 1 & 0 & 0 & 0 \\ x_0 & \dots & x_{n-1} & 0 & 0 & 0 \\ y_0 & \dots & y_{n-1} & 0 & 0 & 0 \end{bmatrix}$$

Solving the equations can get the coefficients $X = [F_1 \ F_2 \ \dots \ F_n \ a_0 \ a_1 \ a_2]^T$. In this way, the number of unknown factors is equal to the number of equations, so we can get the precise solution without the least square method, implementing the pairs of control points' registration.

the Householder translation is used to solve The linear equations use (Zhou Changfa, 2002; Yang Changlan, 2001). The Householder translation is a steady way to solve linear equations. The basic principle is translate $H_1 H_2, \dots, H_r A$ to a upper triangular matrix by seeking Household matrix $H_1 H_2, \dots, H_r$, and then solve the equations easily.

It is more accurate that processes the precise calibration using surface spline function correction than using orthogonal polynomial correction. However, there is more significant distortion using surface spline than the latter one if they are used in other conditions.

3.3 Overlay and display of raster image and vector map

Since the images are translated, precise corrected and re-sampled to gain the actual coordinate, they can be displayed integrated with vector map by using the actual coordinates.

There are two ways for the overlay of the raster image and vector map. One is overlapping the range of the screen coordinates and the actual coordinates of the image to get the coordinates range of the overlay, then read the data from corresponding range of the RS image, to display on the screen in the range pointed by Windows' API interface. The other one is ensuring the coefficient of the proportion of the image displayed and RS image firstly, and then resample the image in the range which should be shown, then display on the screen by the actual size. The second way makes the image more distinct by re-sampling, so we the second way.

The steps of superposition and display are shown below:

1. Get the range of the actual screen coordinates;
2. Get the coefficients of proportion between the range gotten in step 1 and the logic size in pixel unit;
3. Calculate the size of scaled image after the logic size of RS image multiplying the coefficient of proportion;
4. Seek the intersection of the image's range of actual coordinates and the range of screen coordinates, and then get the range of actual coordinates of displaying image;
5. According to the range gotten in step 4, calculate the scaled logic RS image coordinates' range (per pixel);

6. According to the coefficient of proportion of the scaled image and the original image, resample the RGB value in the display area;

7. Get the range of device coordinates in the screen which can be solved by intersecting the image and the screen (attention: the orthoaxis is downward in the device coordinate system), and reconstruct the image to display in a certain range.

3.4 Spatial feature enhanced display image

We always concern only a small part or content on RS image which covers a large area. For example, we only concern the relative location of water areas or rivers and the mining areas when we talk about the influence of the coal mining to the environment. When analyzing the influence caused by the coal mining, as the ground surface sinking, we need to calculate the sinking area. It is significantly meaningful to study how to fast locate, how to get the statistic, and how to display the certain kind of image information which users concerned.

When provide the whole image information, the traditional model of display, limited by the scale of the screen, makes the partial information invisible when the zoom out the image, so it can not display the details that user concerned. How to provide a whole view of the image while displaying the details is also a problem needs to be solved. This paper introduces a spatial feature model, which can stand out the features user concerned by using the entities to denote the features. The scale and the relative location of the entities remain when the image zoom out to a certain scale, so that the user can obtain the information from the image quickly.

The principle to display the spatial feature significantly is: according to the entities' locations in the vector map, make sure their pixel information in the image, and extract the pixel information to construct entities to display on the screen. A map layer is corresponding to a class of vector figure in LongruanGIS platform, so users can choose the map layer to appoint a kind of entities concerned. Users can obtain the whole entities' information according to the chosen layer. The steps are shown below:

1. Get the proportion of image display;
2. Estimate if the display proportion is less than the setting proportion;
3. If less than the setting proportion, process the entities which need to be displayed significantly by enlarge the scale;
4. Resample the image needs to be displayed, judge every pixel if it is included by the entity;
5. If larger than the setting proportion, display in the setting proportion, instead of display as the normal way;

There should be special process when resample the display image if displayed as this model. The concrete ideas are: separate the image to two parts, one parts display as the normal image, the other part needing to display the entities significantly. So pixels should be judged if they are in the normal part or in the part should be emphasize. The steps are:

1. The system need users to set R_{show} as the coefficient of proportion of the entities need to be displayed significantly to get the whole information of the entities. According to that, system firstly judges if one entity should be displayed, adds the entity displayed to a serial list; secondly, calculate R_{stol} as the coefficient of proportion of the size of display image and the logic size of the image; and then ascertain the relationship of R_{show} and R_{stol} , if $R_{stol} < R_{show}$ should be displayed significantly, by magnify the entity R_{show} / R_{stol} times focus on the center of the entity. Contain analyze will be taken to get if the re-sampling point is a part of the entity displayed significantly, if not, display in the normal way. If is, the system should get the location of the entity on the image and the logic image: firstly, get the distance from the point to the center in the image, and the logic distance from the point to the center is calculated by the distance above divided with R_{show} . Then resample according to this logic distance, and reconstruct the entity. Locate the significant entity at the center point of the image.

4. EXPERIMENT

This paper overlaps the QuickBird RS image covered 25 square kilometers of the Getting mine (Shandong Proviencie) with the contrast plan, as is shown in fig 3. Fig 2 is the traditional vector map. Compare with the two figs shows that the new kind of contrast map provides the information more directly: we can get the information of the sinking area caused by mining activity, relative laneway location to the village, objects types in front of the working face, etc. The relationship of the mine laneway and the features up ground is clear in one glance in the overlay map of high resolution QuickBird RS image and the mining engineering plan.

5. CONCLUSIONS

Compared with the traditional surface-ground contrast map, the new kind of contrast maps with the advantages of raster and vector can provide abundant of true and direct information to fast display the dynamic change information of the mining. At the same time, the new kind of maps update more easily: the change of the surface can be updated by registration new RS image, instead of resurveying and remapping. This paper also introduces the display model which magnifies the feature of the spatial characteristics, to zoom in the partial information, blow up the details users concerned.

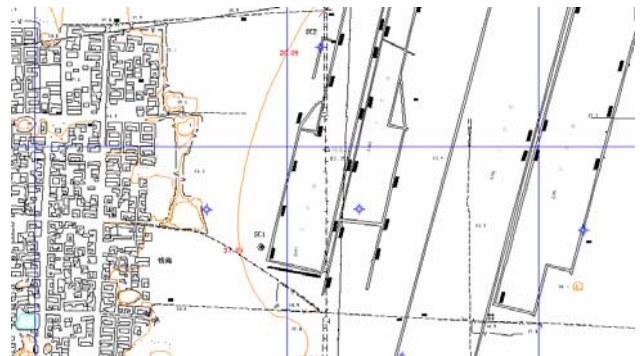


Figure 2. The traditional surface-underground contrast vector plan

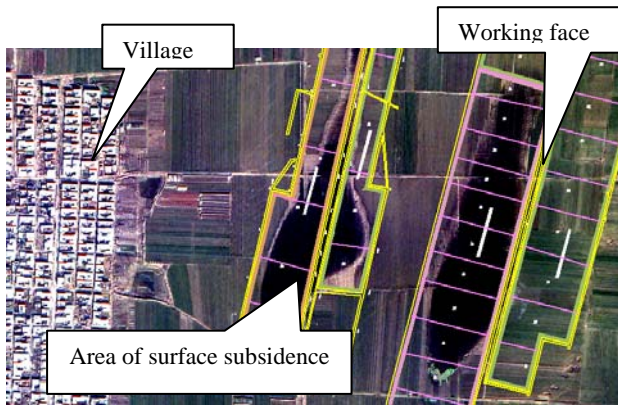


Figure 3. The new surface-underground contrast plan

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