

VISUALIZED APPLICATION OF GIS IN MINING SUBSIDENCE ANALYSIS

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ABSTRACT:

To determine the degree of mining affection on surface or in strata, the GIS technique is used, with Mapinfo as the platform. Through programming of seam inclination-based subsidence mathematical models and mining disturbance analysis visualization, Mapbasic/Vc++/Vfortran programming design is realized under Windows. The program system provides not only an effective approach for model analysis, but also an efficient visual tool and interface for subsidence model application, laying therefore a solid foundation for widespread use of the model.

1. INTRODUCTION ON MINING SUBSIDENCE MODEL

1.1 General Instructions

A new subsidence model is put forward to calculate surface movement and deformation induced by coal seam mining[1,2]. The approach features that: the seam inclination angle, as the most prominent influential factor, among others, governing the pattern of ground movement, is reckoned as a principal parameter while the individual elements in working seams with any dip angles are considered to be surface micro-element vectors which are then resolved according to the parallelogram law; introduction of mining influential functions respectively for vertical and horizontal components of surface micro-element, based on random medium theory; introduction of rock movement parameters irrespective of the occurrence pattern and size of workings; determination of the unit movement trough through integrating both vertical and horizontal components according to equivalent influence principle; development of a continuous mining subsidence mathematical model through surface integral of influential functions over the entire area above the workings, according to the principle of superimposition. A totally new theory and method, so-called vector prediction method that is applicable for seams with dip angles ranging 0-90° is thus developed through combining the seam dip angle based maximum subsidence calculation model, mining influence propagation angle calculation model as well as the design routine of these models' programmed algorithms.

$$W_{eh}(x, y) = \frac{\cos a}{r_h^2} e^{-\frac{\pi x^2 + (y - H \operatorname{ctg} \theta_0)^2}{r_h^2}} \quad (1)$$

dSv is the vertical mining unit with an area of $1 \times \sin \alpha$ and a thickness of 1. It can also be reckoned as a horizontal mining unit with an area of 1×1 and a thickness of $\sin \alpha$. Similarly, the expression for the subsidence basin for the vertical component dSv can be obtained as follows:

$$W_{ev}(x, y) = \frac{\sin a}{r_v^2} e^{-\frac{\pi x^2 + (y - H \operatorname{ctg} \theta_0)^2}{r_v^2}} \quad (2)$$

In Equations (1) and (2):

Weh(x, y), Wev(x, y) – Mining subsidence basins of dSh and dSv respectively

rh, rv – Main influence radii of mining of flat and vertical seams respectively

H – Mining depth of dS at point P

θ0 – Mining influence propagation angle

By superimposition of the subsidence basins of the horizontal component and vertical component, we obtain the expression for the subsidence basin for dS:

$$W_e(x, y) = W_{eh}(x, y) + W_{ev}(x, y) \quad (3)$$

Considering the orthogonality of the micro-unit vector's two basic components of dSh and dSv, we have:

$$\begin{cases} \iint_S W_{ev}(x, y) dS_h = 0 \\ \iint_S W_{eh}(x, y) dS_v = 0 \end{cases}$$

and hence

$$W_{(x,y,z)} = W_{\max} \left[\iint_S W_{eh}(x, y) dS_h + \iint_S W_{ev}(x, y) dS_v \right] \quad (4)$$

As can be seen from Equation (4), the rock and surface movements caused by mining of a pitching seam may be attributed to two mining influences. One is the influence produced by the horizontal component and the other by the vertical component. The superimposed area of the horizontal mining component is equal to the projected area of the working face on the horizontal plane; while the superimposed area of the vertical component is equal to the projected area of the working face on the vertical plane. Therefore, the horizontal and vertical projections can respectively be taken as the field of integration in the integration operation. The integrand is the function in the domain of area of S with varying Z coordinates. The significance of Equation (4) lies in that it enables the integration over the domain of area S to be converted to integration over its vertical and horizontal projected areas. This lays the foundation for the design of the algorithm of the vector method.

According to the basic theory of ground movement, there exists a functional relation between ground movement and the

various surface deformations and movements. Because of the independence of the influence function and integral variables, the functional relation existing for a complete subsidence basin can be referred to from the subsidence basin due to unit mining — so as to derive the influence functions of individual mining-induced movements and deformations.

2. THE ESTABLISHMENT OF THE MINING SUBSIDENCE ANALYSIS SYSTEM

2.1 The Idea of the System

In order to establish the Mining Subsidence Analysis System (MSAS), many factors need to be considered, the prediction calculation model, the parameter model, data sharing, mathematic design, and computer language before the program will work. The designer is required to have a very general and clear design sense in the research and development process of the MSAS. The idea of the system contains as follow:

- 1) The whole MSAS is based on the MapInfo system, which was also used to develop the MSAS. The function of compatibility, data transfer and data exchange are found in the main control menu, these functions are used to establish a relationship between the Mapinfo system and the prediction calculation process. The advanced analysis function and graphics function are used to make MapBasic program, which help to achieve the visual analysis of mining inflection.
- 2) The C and Fortran language with their advanced speed in making calculations will be used to program the prediction system, the parameterised function and the protraction of section curve and isoline. Making program in the system of Visual C++ and Visual Fortran, it will makes executable files in Windows and achieve high compatibility with MapInfo. AutoCAD is used as the secondary mapping tool, or graphics exchange method.

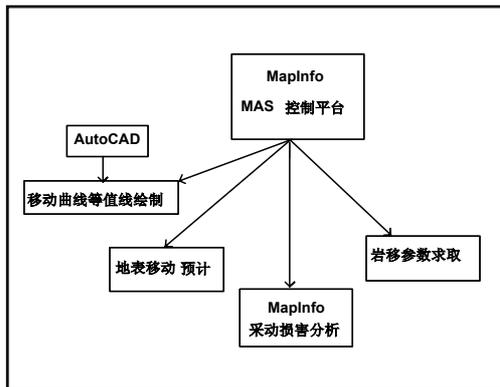


Figure 1. The constitute diagram of mining subsidence analysed system (MSAS)

2.2 The Frame of the System

The establishment of MSAS system, is to realise the function of prediction and calculation of ground displacement and deformation. Figure 1 shows the constitute diagram of the MSAS system. And Figure 2 is the control platform of the system. The control platform of MSAS system transfer other sub process and run the executable files compiled by Visual

C++ and Visual Fortran system. Control platform is achieved by the program of MapBasic, partial source program shows on Table 1.



Figure 2 Control platform of MSAS

```

'yjmenu.mb
Include "mapbasic.def"
Include "icons.def"
Include "menu.def"
Declare Sub MAIN
Declare Sub qxyj_sub
Declare Sub jqxyj_sub
Declare Sub vector_sub
Declare Sub dzxd_sub

Sub Main
  'Establish Menu for designing system
  Create Menu "地表移动分析系统" As
    "&倾斜预计" Calling qxyj_sub,"(-",
    "急倾斜预计" Calling jqxyj_sub,"(-",
    "采空区矢量法预计"
      calling vector_sub,"(-",
    "绘等值线" Calling dzxd_sub,
    "绘变形曲线" Calling bxx_sub
  Alter Menu bar add "地表移动分析系统"
  Alter Menu "地表移动分析系统" Add "(-",
    "急倾斜求参" As "急倾斜求参"
  Create Menu "GIS 可视化" As
    "&采动分析" Calling cdfx_sub,"(-",
    "可视化" Calling visual_sub
  Alter Menu "地表移动分析系统" Add "(-",
    "GIS 可视化" As "GIS 可视化"
End Sub
Sub Ryxd_sub
  'Run program "d:\gcgsany"
  'Run program "d:\qxyj"
End Sub
    
```

Table 1. Partial MapBasic source program

2.3 The Content and Function of MSAS System

The content of the MSAS system, contains not only mining subsidence model based on dip angle transformation and program format of vector prediction method, which are established in this paper, but also the contents of the traditional prediction and program format of parameter method. The main content and function shows below:

- The program format of vector model, do the surface displacement prediction and parameter analysis.
- Probability integral prediction and the determination of parameter.

- Person III function prediction a parameterised
- Visualized analysis of mining subsidence, including deformation analysis, water area analysis, reclamation analysis
- The protraction of displacement and deformation curves
- The achievement of plane analysis and 3D view

2.4 The Achievement of Prediction Program

The displacement calculation of the surface is the hard core of the MSAS system; it is the basic work of doing the mining analysis and achieving other functions, which also supply the basic date of mining subsidence for the system. Therefore, the veracity of the prediction calculation result connects to the reliability of the whole system’s run result, which is the important tache of the system design.

Take vector program as an example; explain the system environment of the system design and the format and method of date transfer, the basic program mode is :

- (1) Use C language and compile in Visual C++ system, transferred by MapInfo system or solely run in Dos/Windows.
- (2) Structuralized programming, the design of the program structure based on affirmatory relationship and organize sub program based on function.
- (3) The date of mining condition and calculation point are supplied by the known date files; the transfer and control parameters are confirmed by man-computer conversation during the process.
- (4) The result of the calculation is output by the general format, so that it can still be used afterwards.

The Specialty Functions of the Vector Prediction Program

- (1) It can predict the mining displacement of horizontal, flat, dipping, high dipping and vertical coal. The wide adaptability of the program to dip angel is based on the mining model dip angle transformation; It also solve the singular problem caused by the boundary condition ($\alpha = 0^\circ, 90^\circ$).
- (2) According to the mining condition around the working face, choose the calculation method--based on side or based on points, it can establish more veracious calculation boundary.
- (3) The program adopt the method of integral region of strike partition based on junction points, which avoid the trouble caused of block prepared date caused by the shape of polygon working face. It makes the program can adapt any shape of the working face (including the inside concave situation of the dip and strike), reduce the workload of date preparing.
- (4) The calculation points is sorted by three modes: scattered points, calculation line and calculation net, which all service for all kinds analysis purpose.
- (5) The calculation result is: any shape of the mining on multiplicative working face, surface calculation points is the movement and deformation value along any specify.

The Program Achievement of Mining Analysis Function
 There are two approach to achieve the mining analysis function: One is based on the system function of Mapinfo and Mapbasic program, which is the main analysis methods of this system;

The other is based on section curve and isoline program. Now, explain the analysis function of MapInfo and Mapbasic program.

First, the analysis model based on MapInfor system and Mapbasic program will predict the result and establish table files with the date format of Mapinfo system; Second, the sub process of object-specific analysis is achieved by the MapBasic program, or achieved by the Mapinfo platform system directly.

3. THE APPLICATION OF THE VISUALIZED ANALYSIS SYSTEM

MSAS is finished by debugging and complementarities, though it still has some unsolved problems, such as the complete date share. But, the application is only the skill and technique problem when the system is established. Thereinafter, will introduce several digs show the application of MSAS in mining subsidence.

3.1 Visualized Analysis for Horizontal Seam Mining

A certain coal mine belongs to flat coal seam, the obliquity of the coal mine $\alpha = 6^\circ$, the thickness of exploitation is 8.22m and the depth of exploitation is 300~600m. Using the MSAS System analysis the exploitation surface deformation of District No.5. Fig 3 is Distribution and area inquiry of mining influence of Grade II and over (tension deformation, more than 4mm/m; tilt, more than 6mm/m)

3.2 Visualized Analysis for Steep Seam Mining

Another coal mine is steep coal seam, the obliquity of the coal mine $\alpha = 60^\circ$, the thickness of exploitation is 5m, the phase vertical height is 150m and the depth of exploitation is 580m. Using the MSAS System predict the maximum subsidence of surface is 1390mm. Fig 5 is the distribution of ground subsidence due to steep seam mining (seam’s dip angle $\alpha = 60^\circ$), Fig 6 is the distribution of horizontal deformation due to steep seam mining, tension in red area, compression in blue area.

The two cases show that MASA system can satisfied analysis require of different levels obliquity coal steam, the application of MASA acquire favorable achievements.

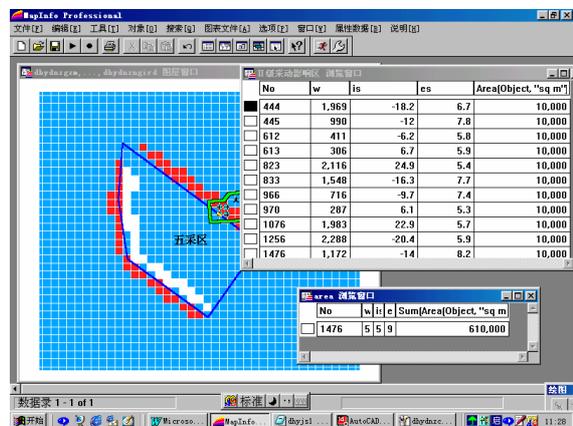


Figure 3. Distribution and area inquiry of mining influence of Grade II and over

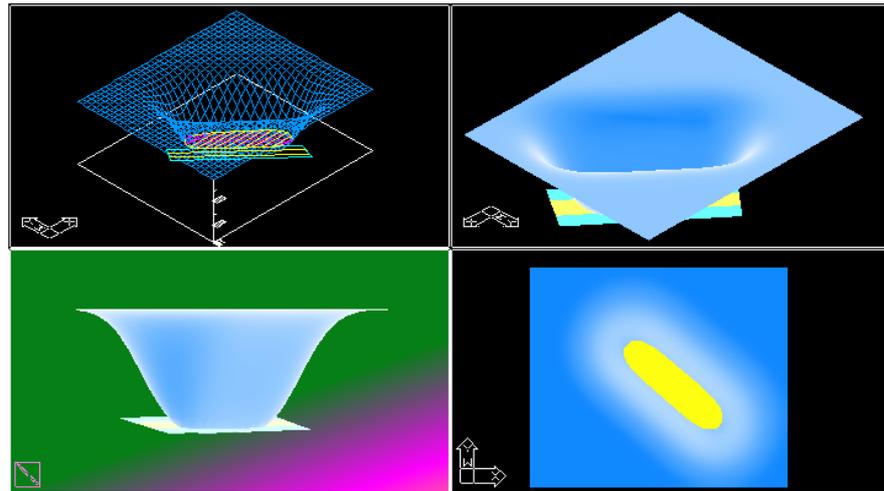


Figure 4. 3D subsidence trough induced by three-face horizontal seam mining (Water area in shadow, $W=400\text{mm}$)

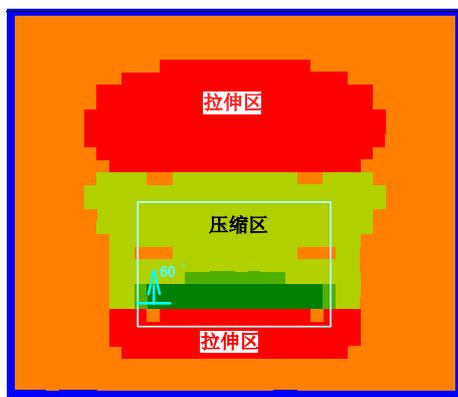


Figure 5. Distribution of ground subsidence due to steep seam mining

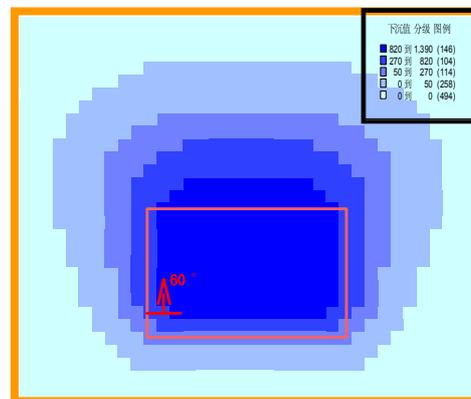


Figure 6. Distribution of horizontal deformation due to steep seam mining

4. CONCLUSIONS

This paper introduces the basic knowledge and application method of GIS, discusses the basic contents of the MapInfo system and its platform Mapbasic. The application of the above system and platform, structure the vector prediction model and other MSAS prediction model. The application of MSAS achieve the goal of mining analysis and visualized application.

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