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Design and Implementation of Mine Information Management System Based on Wireless Network

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Abstract: With the increasing demand for mineral resources in China, how to manage mineral resources scientifically, efficiently and intelligently has become a practical problem faced by relevant governments, enterprises and academia. As the most advanced technology of GIS in recent years, Web GIS can collect, store, process, analyze and visualize heterogeneous, multi-source and massive spatial geographic data. Therefore, introducing Web GIS technology into mine information management and building an information system for massive, multi-source and heterogeneous mine information management is of great significance for the government and enterprises to improve the management efficiency of mineral resources and realize the accurate and scientific planning and management of mineral resources.

Keywords: GIS, GPS, GPRS, Linear programming, Ore blending, Open pit mine.

1. Introduction

Ore blending is an approach to program and manage ore quality. It mainly improves the uniformity and stability in the quality of minerals and mineral products, makes full use of mineral resources and reduces the volatility of ore grades, raising labour productivity of ore dressing, improves the quality of the products and reduces production costs. There are two aspects to ore quality control. The first one is the short-term quality plan of production in a mine. It is made to conform to the annual plan and conditions of the stope. This plan is drawn up, organized and implemented daily, weekly and monthly. The second aspect is process control in mine production. It is implemented by gradual control in all processes of exploitation and processing according to the output of ore and the characteristics of different production processes. Thus, mineral quality control is a process of making an ore blending plan and ensuring comprehensive control in implementing this plan [1] .

Today, the management system of ore blending in developed countries has matured. In some mines, special measures, adapted to local conditions, have been taken to control ore quality. Especially, computer technologies are applied to control and manage all processes of mining, transportation, processing and storage in the control of ore quality. For example, in the Minntac Mine, USA, an orderly approach of loading by shovel and unloading from railway wagons has been adopted to control the balance of ore quality. The ore quality control system dispatches trucks and railway cars by computer. It can dispatch trucks and trains according to certain indicators of production and ore blending. As well, it monitors the conditions of equipment by a remote control device.

Simultaneously, this system maintains ore quality and operating equipment in an optimal state. Computer networks of ore quality control have also been applied in other developed mines such as the Newman iron ore and Paraburdoo mines in Australia. They keep on-site working information seamlessly connected with a control center. The produce in the stope complies strictly to instructions of ore production operations, which are released by the quality control center.

Another example is the dispatch system of the Hibbing Taconite Company in America. Its computer control center is connected with the vehicles dispatched by computer in this system. With the communication terminal of dispatched vehicles and other information terminals, the operators have a good command over each process in ore blending according to the changes in ore quality [2] . The fundamental reason for their success in ore blending management is a strict and meticulous quality control system and scientific, advanced technical means to enforce it.

In most domestic mines, many ore quality control systems have only recently implemented computerrelated technologies to establish ore blending models, such as linear programming, 0-1 integer programming and so on. These models allow short-term quality production plans in mines. Examples are the computer auxiliary optimum blending ore systems of the Baiyun Iron Ore, the system for low-grade pyrite ore in Yanfu and for the Zhujiabaobao iron ore. However, these systems can not control and manage the entire ore production process in real time. Control of an entire ore production process is one of the most important aspects to maintain stability in ore quality. So, our study proposes the use of GIS/GPS/GPRS technologies and a linear programming model. The proposed system can implement control of ore quality in real time, automatically draw up a scientific and rational short term ore blending plan and dynamically track, dispatch and manage production equipment to implement ore blending in an open pit mine. This is of great importance for improving the level of ore quality control of digital mines in our country.

2. GIS/GPS/GPRS

The Geographic Information System (GIS) is one kind of computer system for gathering, storing, managing, analyzing, demonstrating and applying geographic information. It is a general technology that can analyze and process enormous amounts of geographic data. GIS has been applied in many fields to establish all kinds of spatial databases and decision support systems, each with different criteria and provide answers to many different formal spatial inquiries, spatial analyses and assistance plans and decision-making functions. To date, GIS has been gradually applied in open pit mines [3] .

The task of a dynamic management system of ore blending in open pits is to track, monitor and manage production equipment, which depends largely on spatial geographic information. Therefore GIS plays an important role in visual supervisory systems of ore blending, real-time dynamic management and assistance in decision analyses.

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed in orbit. Their ground stations are managed by the U.S. Department of Defense [4] . With four or more satellites in view, a GPS receiver can determine the 3D position of shovels (latitude, longitude and elevation) and track movements. Once the position of the shovel has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, sunrise and sunset time and more. GPS works in all weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or establishment charges to use GPS. With GPS, the dynamic management system of ore blending provides accurate position (latitude and longitude), speed, bearing, time, track and more basic information of trucks and shovels. Besides, the accurate position of muck-pile boundaries and blasting holes can be calculated by GPS units. The ore quality of these pile boundaries and blasting holes can be monitored on electronic maps.

The General Packet Radio Service (GPRS) is one of GSMPhase2+ standard realization systems and can provide fast data transmission speeds [5] . It provides end-to-end, wide area wireless IP connections and has remarkable advantages in many other areas. The dynamic management system of ore blending in open pit mines largely uses some of the advantages of GPRS, such as faster speed and instant connections, when the need arises and is charged by the amount of data generated. It can provide real-time wireless transmission and is very quick without a dial-up modem connection to GPS equipment for position information. That is very important because GPS position information has room for only a small amount of data and needs to be transmitted frequently. So this system can make good use of GPRS to transmit GPS position information and other information such as dispatching commands and ore grades.

3. Principle of Dynamic Management System of Ore Blending

3.1. Structure of Ore Blending Management System

The dynamic management system of ore blending is composed of mobile terminals carried by vehicles, a communication network and a dispatch center, as shown in Figure 1.

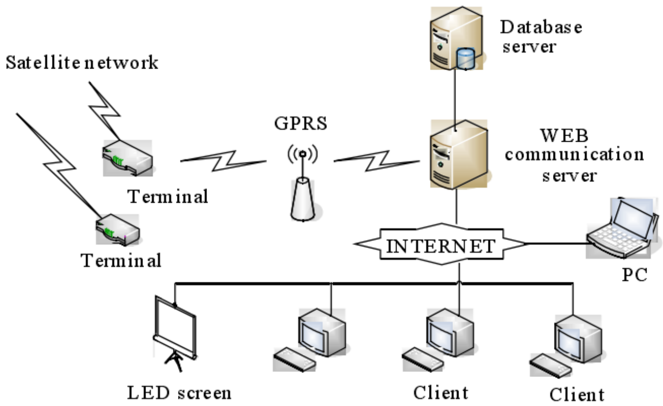

Figure 1. Structure of dynamic ore blending management system

In this system the mobile terminals receive GPS signals and then calculate latitude, longitude, angle, elevation and speed of the vehicles. The expansion interfaces of mobile terminals can also connect to many examination and control lines to obtain the information from the vehicles. Each kind of information is transmitted to the monitoring center through GPRS and the internet. GPRS, as a telecommunications network between the mobile terminals and dispatch Mining Science and Technology Vol.20 No.1 134 center, mainly transmits information on position and condition of the vehicles, as well as information in case of an alarm, to the dispatch center, which in turn transmits dispatches and control commands to the vehicles. In the dispatch center, the communication server, the database server and the console are connected by a 100 M local area network. The dispatch center, under control of the system software system, receives and processes all kinds of information coming from the controlled vehicles. The position, ore grade and other information of the shovels are displayed at multimedia monitors and electronic maps in the dispatch center and from these the vehicles can be monitored and dispatched [6].

3.2. Linear Programming Model

3.2.1. Modeling

We established. a model for a number of shovels and crushing stations for an actual mine production. Assume that the number of shovels is m, the number of crushing stations n, the amount of ore from shovel (i) to crushing station (j) is x ij , the ore grade (f) supplied by shovel (i) is g fi , the ore grade (s) needed by crushing station (j) is g sj . The constraint conditions are as follows [7]:

1) Amount of ore supplied and production capacity of shovels. The amount of ore supplied by shovels should be within their range of production capacity and meet the requirement of production, i.e.,

$$Q_i \le \sum_{i=1}^{m} x_{ij} \le A_i \quad (i=1,\ 2,\ \cdots,\ m) \qquad (1)$$

where x ij is the amount of ore supplied by shovel (i) for crushing station (j), A i the maximum amount of ore shovel (i) can supply and Q i the production task of shovel (i).

2) Minimum task of crushing station. In the ore blending plan, each crushing station will be assigned a minimum task. Assume that the minimum production task (r) of crushing station (j) is Q jr , i.e.,

$$\sum_{i=1}^{m} x_{ij} \geq Q_{jr} \tag{2}$$

3) Non-negative constraints. The amount of ore supplied by a shovel to a crushing station cannot be negative, that is:

$$x_{ij} \geq 0 \quad (i=1,\ 2,\ \cdots,\ m;\ \ j=1,\ 2,\ \cdots,\ n) \tag{3}$$

4) Objective function. The target ore grade of the mine is g and its error range should be less than 5%. According to the actual production of the mine, the deviation from actual ore grade and target ore grade at every crushing station should be minimized by the objective function, i.e.,

$$\min s = \sum_{j=1}^{n} \left| (Q_1 \cdots Q_{j-1} Q_{j+1} \cdots Q_n) \sum_{i=1}^{m} x_{ij} g_{fi} \right| \tag{4}$$

where, g fi is the ore grade supplied by shovel (i) and Q j the task of crushing station (j). According to the actual mine requirement, this model is optimized by adding a new constrain, i.e.,

$$\left| \sum_{i=1}^{m} x_{ij} g_{fi} \right| \geq Q_j g_{sj} \tag{5}$$

3.2.2. Solution

The model is solved by a two-stage method. In the first stage, many new non-negative variables (x n+1 , x n+2 , …, x n+h) are added to the model. Its purpose is to ensure that the m-moment unit sub matrix is included in the coefficient matrix A (A =(b ij) m×(n+h) (i=1, 2, …, m; j=1, 2, …, n, n+1, …, n+h)) of the newly composed initial simplex tableau.

At this first stage, the sum of all added artificial variables is minimized, i.e., the objective function is:

$$\min \quad Z_1 = \sum_{i=n+1}^{n+h} x_i \tag{6}$$

If the optimal solution of Z 1 =0 can be obtained, all the added artificial variables are non-basic variables, while the m original variables, before the addition, are basic variables. This leaves an m-moment unit sub matrix in the coefficient matrix when the corresponding column of artificial variables is deleted and it is assumed that this is the initial feasible base B 0. Then we turn to the second stage of the two-phase method to solve the problem. Otherwise, there is no feasible solution for this problem.

4. Dynamic management system of ore blending in the Sandaozhuang open pit mine

The Sandaozhuang open pit mine is part of the Luoyang Luanchuan Molybdenum Industry Group Inc. Its output is 10 million ton. Its length is 2350 m, its width 1350 m and its mining elevation is between 1114 and 1630.8 m. Mining takes place over a vertical distance of 516.8 m and the bench height is 12 m. Rotary drilling machines, shovels and trucks are used in this mining process. The transportation system consists of a number of trucks, three crushing stations, an ore pass and electric locomotives. The dynamic management system of ore blending in this open pit consists mainly of terminals and management software for ore blending. The software system is composed of modular subsystems.

4.1. Software Constitution and Its Function

4.1.1 Dynamic Ore Blending Management Subsystem

The function of this subsystem is mainly to implement the production management of ore blending for shovels in the dispatch center, including the automatic drawing up of an ore blending plan and real-time dynamic monitoring and control in the mining operation process of shovels. Its main functions are as follows:

1) Map operation: zoom in, zoom out, roam and display lamination maps; display coordinates of a random point on maps; compute the distance between two random points; compute the area of a random polygon; obtain information about the geographic target, etc.

2) Management of muck-piles: import the coordinate data of the holes, the boundaries of muck-piles and ore grade of holes; this permits these holes and boundaries to be shown on electronic maps; given the ore grades of holes and other properties, randomly shaped ore blocks on maps can be selected by circles or polygons and their average grades of ore and their quantities can be calculated automatically.

3) Drawing the isolines of ore grade: on the basis of data from muck-piles, different grade values can be randomly established and according to this, different isolines of ore grade can be drawn in different colors on maps; the amount of ore in different areas, divided by isolines, can also be calculated.

4) Display of shovels: display each shovel and its different ore grades, e.g., by different ways, different colors and different marks in real-time; don't display of shovels and ore grades according to given commands.

5) Playback of historical paths and ore grade: permits play back of the travel path of any shovel at any time and display its historical ore grade mined on electronic maps.

6) Location of shovels: permits inquiry of current position, operating radius, condition and driver of any shovel at any moment.

7) Instruction dispatch: given the ore grade of any shovel in real time on an electronic map, the dispatch center can send out dispatch instructions as text to dispatch the shovels and call any terminal; the terminal carried by shovels will clearly indicate and display, with a red light and phone, the dispatch instructions on the terminal.

8) Terminal information feedback: the terminal carried by shovels can upload the prefabricated fixed information on the operation surface of the terminal and return feedback to the dispatch center which can deal with the information in a timely fashion.

9) Making an ore blending plan: the linear program can arrange the plan of ore blending for every day according to the current ore grade, the loose ore coefficient and ore lithology of the work zone, the production capacity of shovels and the task, capacity and target ore grade of the crushing station.

10) Other functions: the expanding interface available to the system can be integrated with the GPS monitoring system of trucks and weighing system of ore; at any time inquiries can be made about the amount and grade of ore crushed; it is useful for the dispatcher to hold dynamically the progress of the plan of ore blending.

4.1.2 Data communication control server The communication control server mainly gathers, transmits and routes the data through the TCP/IP and analyzes the communication protocol and the distribution of data. This part is also in charge of the handling of traffic (monitoring, dispatch etc.) and other data connections (localization of data input, condition, renewal of vehicles, etc.).

4.1.3 Database management system The database management system mainly manages the database and increases, deletes, modifies and requires data from shovels, drivers and operators; it regularly backs up the data and then deletes it.

4.2. System Deployment

The entire system deployment is as follows:

1) Terminal installation: high precision GPS terminals had been installed in 20 shovels during an earlier period. The terminals consist mainly of a high-performance mainframe, a GPS antenna, a GPRS antenna, a display, a red indication light, earphones, a sound box as well as a microphone. After installation, the terminals need debugging. This mainly sets the parameters of the main frame (number, IP, port, etc.) using an operation handle.

2) Software deployment: there are three sub-systems in the project. The data communication control system is deployed in the web server of the company; the database management server is deployed in the database server of the company and the dynamic management system of ore blending is deployed in the dispatch center of the open pit.

3) Coordinate registration: in first instance, the present topographic map of the open pit should be renewed. Under AutoCAD2006 we can transform it from DWG to DXF format. Then we can match the present DXF topographic map to the coordinates. Establish a longitude/latitude (wgs84) coordinate system and select a couple of coordinates: the geodetic coordinates of the first point are: (6755.3044, 4850.7990), its latitude/longitude coordinates are (111.506202, 33.91905); those of the second point are (6459.1221, 5482.2094), latitude/longitude coordinates (111.50295, 33.92468). Their match is shown in Fig. 2. After obtaining the electronic map of Tab format, the electronic map is saved as Geoset by MapX5.0.

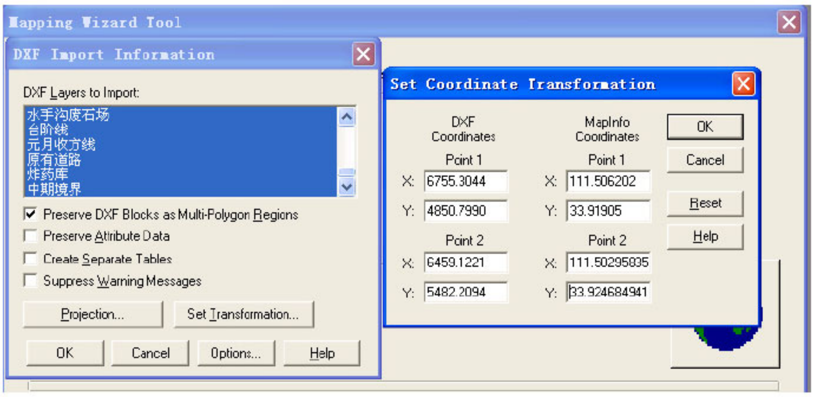

Figure 2. Coordinate registration Mining Science and Technology Vol.20 No.1 136

4.3. System Application

The dynamic management system of ore blending in the Sandaozhuang open pit mine has been used since May, 2008. From continuous on-site testing, it is seen that the entire system is working well. Typical applications are:

1) Making a daily ore blending plan: the process of making the ore blending plan is essentially a human-computer interaction protocol. So, if some unusual conditions occur, dispatchers can be flexible and adjust the parameters of ore blending at any moment. The rationality and practicality of this plan is very well ensured. Given the requirements of the Luoyang Luanchuan Molybdenum Industry Group Inc., the ore grade should meet the established standard and is not permitted to be more than 5% off. There are many benches mined in the open pit and the ore grades vary widely in different benches. There are 8~10 shovels working and three crushing stations in each shift (three shifts per day). The relevant parameters of the ore blending plan for a particular day in the open pit are shown in Table 1, where 10 shovels and three crushing stations involved. The target ore grade should be between 0.114% and 0.126% and the amount of ore should be between 16.005 and 16.995 thousand tons. The ore blending plan designed is presented in Table 2, which shows the optimal solution according to the actual production and linear program for the open pit.

Table 1. Key parameters of ore blending

Shovels	Gp (%)	Min (t)	Max (t)	Cs (t)
1#	0.115	600	2000	(0,2000)
2#	0.132	550	1950	(0,2000)
3#	0.106	500	1950	(0,2000)
4#	0.09	600	2000	(0,2000)
5#	0.108	600	3000	(0,2000)
6#	0.186	700	3200	(0,2000)
7#	0.114	450	2000	(0,2000)
8#	0.091	600	3000	(0,2000)
9#	0.125	500	2900	(0,2000)
10#	0.19	600	3000	(0,2000)

Note: Gp is the grade provided by shovels; Cs is the target amount that shovel must provide to crushing station. The production task of crushing stations is 5000 t (1#), 8000 t (2#), 3500 t (3#).

2) Dynamic tracking and control of ore blending production: in the dynamic management interface of ore blending, the ore grades and real-time location where the shovels are workings are monitored on the electronic map and dynamically displayed. Thus dispatchers can duly dispatch the shovels according to their current ore grade. Through the ore weighing system and truck dispatching system, dispatchers can keep the amount of the remaining ore in the current muck-piles and the actual loads of the shovels in real time and dynamically adjust and dispatch the shovels and trucks according to the ore blending plan. In addition, the ore grade and amount of ore handled by shovels can also be displayed at the terminal screen of the shovels. It is very useful for the operators to know the current ore grade and actual workload. The state of the shovels is shown in Figure 3.

Table 2. Ore blending plan for one shift Crushing stations (loads)

Shovels	Crushing stations (loads)			Tc (t)	Step (m)
	1#	2#	3#		
1#	20	40	30	17	1330
2#	40	50	0	23	1306
3#	40	50	30	19	1294
4#	30	50	20	17	1438
5#	40	50	20	32	1318
6#	0	50	0	19	1450
7#	0	20	20	23	1438
8#	50	50	0	19	1454
9#	0	0	30	23	1414
10#	20	20	20	17	1426
Sum1 (n)	240	280	170		
Sum2 (t)	5100	7930	3550		
Sum3 (%)	0.115	0.12237	0.12177		

Note: Tc (t) is the average load for some kind of trucks. The unit of the amount of ore supplied by shovel for crushing station is number of truck loadings.

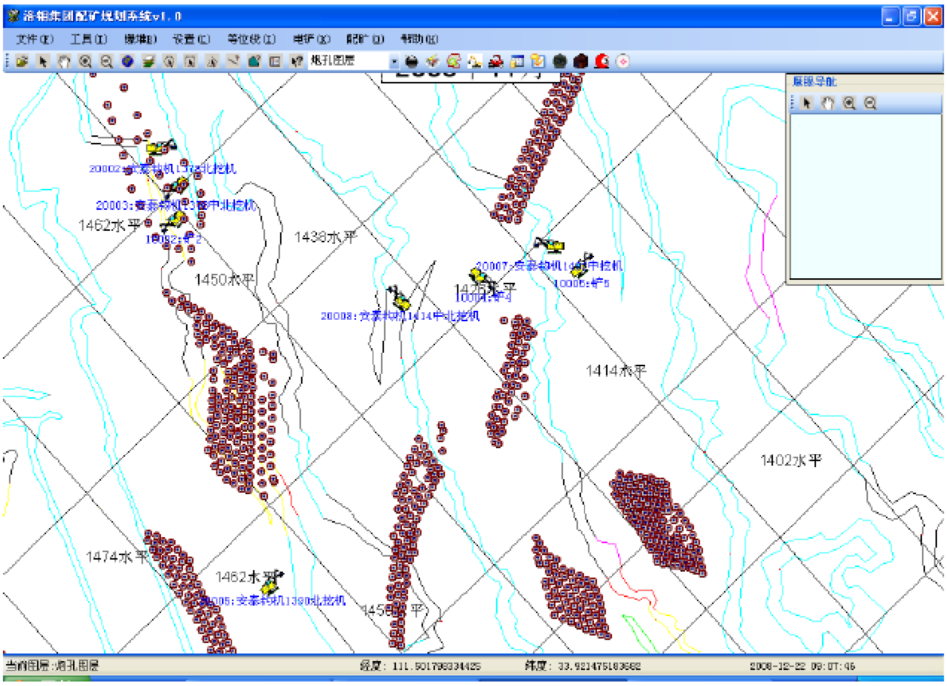

Figure 3. Production state of shovels in the stope

3) Application results: the ore quality in the Sandaozhuang open pit varied considerably due to factors such as ore blending given the subjective experience of operators, cavities formed by underground mining and nonstandard production in the stope. After the application of this system, the ore quality was based on an overall consideration of various factors, such as ore reserves in the stope, the distribution of ore quality, the status of ore mining, the blasting situation, status of the shovels and the indicators of production planning. On the one hand, the system overcomes the shortcomings of making ore blending only from incidental experience. It places the ore blending plan on a scientific footing; on the other hand it can monitor and control the process of ore production and regulate the production in the stope in an orderly fashion. The statistical data shows that the range of error in the ore grade to be off target decreased from 15.82% to 4.35%. The system further guarantees the stability and uniformity of ore quality and provides a good foundation for the flotation in ore dressing. Dynamic monitoring of the ore grade is shown in Figure 4.

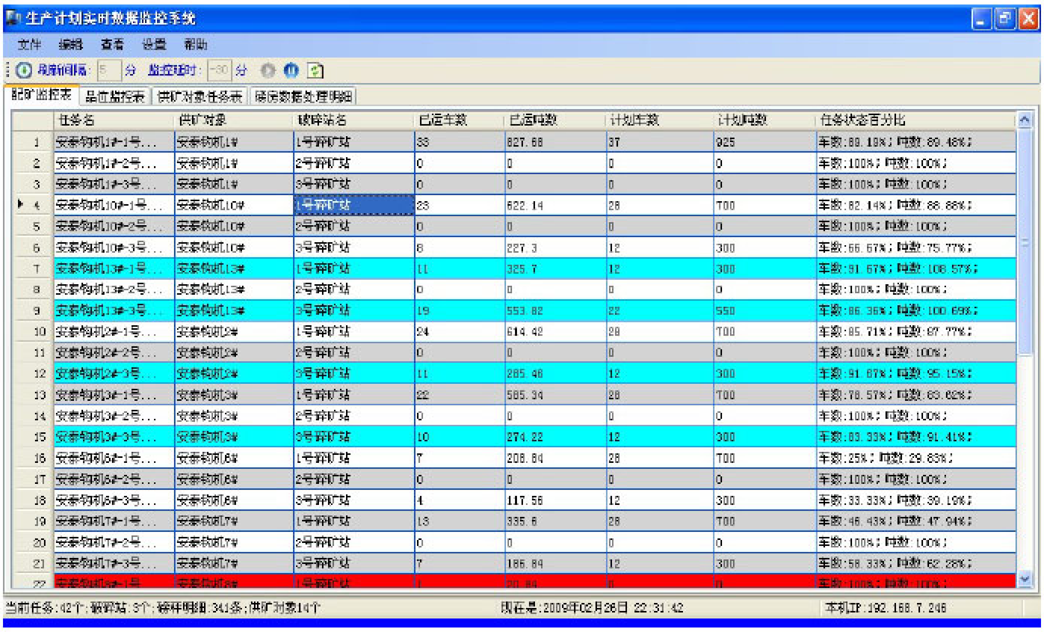

Figure 4. Surface of ore grade monitoring

5. Conclusions

1) The dynamic management system of ore blending in an open pit based on GIS/GPS/GPRS uses technologies from space, wireless location, wireless communication and computers to control the ore quality in an open pit mine and ensures the stability of the ore grade. It improves the productivity of the mine and saves production costs of the enterprise considerably.

2) By means of linear programming, the system has moved away from its irrational and subjective experience in making ore blending plans. It reduces the effect of human factors in the production process and provides a scientific basis for ore blending in open pit mines.

3) The system is of great importance in the realization of automation and information technology in one open pit, which can definitely be applied to other open pit mines.

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