

COMPUTER PROGRAMS FOR DESIGN AND MODELLING IN MINING

Miladinović Milena¹, Čebašek Vladimir², Gojković Nebojša³

Abstract: Information technology (IT) have changed the way we live and work. Mining is no exception. Application of IT in mining is represented in the processing and data management, using software packages for 3D design, modeling and integration of spatial databases with application of the results. In contemporary practice the application of mining computer program (RRP) is significantly expanded and can be concluded that the computer aided design has become a common way of developing mining projects. Developed as a professional software packages for the general mining applications, specialized software packages for optimization of surface or underground exploitation and specific purpose software packages for analyzing problems related to the design of mines or design of exploitation technology. The paper presents traditional and contemporary design methods in mining. Computer programs that make up the support of the design and modeling in mining are also included. Examples of computational models of individual deposits and mining activities are shown.

Key words: mining, computer program, design, modeling

1. DESIGN AND METHODS FOR MODELLING IN MINING

Traditional methods for designing and modeling of open pits and underground mines, are based on manual calculations of mining parameters and manual graphic interpretation of maps, contour surface mine, landfill, dump sites. The basis of this method is a long time for data processing and design of optimal solutions, which significantly complicates the work.

IT enables faster, better and more creative work. IT applications in mining, allowed development of new methods for open pit designing and underground mines, which is significantly different from traditional methods. This methods was called the **modern methods of design and modeling**. The basic assumption for its application is that the adequate *database of geological and mining data*, as well as the *model of the deposit* must be formed.

Modern methods for designing and modeling are based on the integration of IT with mining activities. In some countries, modern design and modeling methods have been used for thirty years, while in the South East and East Europe optimal pits designing is based on traditional methods.

¹ University of Belgrade, Faculty of Mining and Geology, Đušina 7, 11000 Belgrade, Serbia,
e-mail: milena.gojkovic@rgf.bg.ac.rs

² University of Belgrade, Faculty of Mining and Geology, Đušina 7, 11000 Belgrade, Serbia,
e-mail: vcebasek@rgf.bg.ac.rs

³ University of Belgrade, Faculty of Mining and Geology, Đušina 7, 11000 Belgrade, Serbia,
e-mail: ngojkovic@rgf.bg.ac.rs

The main differences between traditional and modern methods of design are given in Table 1.

Table 1 - Comparative review of methods of design and modeling in mining

Traditional methods	Modern methods
<ul style="list-style-type: none"> - manual processing of data, - long time for data processing, - starting point is geological determined ore body or deposit, - application of geometrical analysis, - analysis of the stripping ratio, - high costs of project, - small investments, obtain approximate results of processing, - allow only 2D. 	<ul style="list-style-type: none"> - computer-supported data processing, - significantly shorter period of time for data processing, - starts with the development of computer models of the ore body (dividing it in to the blocks), - blocks analysis based on the optimal mining sequence, - low cost of project, but require greater investments in computer equipment and computer programs, - obtaining accurate data processing, - enable 2D and 3D display of all objects.

Generally, current methods have a far greater advantages over the traditional, and in the future they will be more and more applied.

2. TYPES AND CHARACTERISTICS OF MINING COMPUTER PROGRAMS

The new IT are based on the latest achievements in the development of computer equipment, software, communications and satellite navigation technology, robotics, artificial intelligence, measurement and control techniques, fuzzy logic and systems analysis. The essence of IT applications in the mining industry is reflected in linking the functions of planning, designing, monitoring, analysis, discussion and feedback control of activity through increased production, productivity, reliability, operational safety and operability. This concept of the work activity leads to utilization of information-management systems, multi-stage hierarchical logic, with the built in artificial intelligence, high supervision and control efficiency and developing a new generation of "intelligent" mining machines – robots (Vujić, 2010).

Mining engineers have the opportunity to follow events in the production process from the command center and redirect orders and instructions for the execution of technological operations such as drilling, blasting, loading, transportation, mineral processing, waste disposal, etc.. The benefits of introducing IT into the mining are numerous (Vujić et al. 2008).

Computer programs for defining and optimizing the open pit mine contour, landfill and production planning, are the basis for process control in the open pit mines design. There are currently many professional software packages, which include economic evaluation of open pit mine, the geology of the ore body, transport communications and other technological processes. Great number of other programs for general purpose are used in addition to specialized programs for surface mining.

There is almost no surface mine where engineers do not use any of the computer programs to assist in the implementation of specific project solutions. Number of software packages manufacturers and experts for mining, is constantly growing (Savić, 2003).

Modern computer programs use different methods as the basis for the development of applications, some of which are commonly applied methods **Lerchsa-Grossman (LG)**, **Floating Cone Method** and **dynamic programming**. LG method has the lead over other methods of design.

Computer programs that are used in mining, according to the purpose, can be divided into the following groups:

- **general-purpose software packages:** mining computer programs for modeling and design of mining deposits by the means of surface and in underground mining,
- **specialized software packages** for optimization of surface and/or underground mining exploitation and analysis of the metallic and non-metallic minerals exploitation and
- **specific application software packages**, designed for the analysis of specific problems related to the design of mines or the design of exploitation technology, for example: mining cost analysis, analysis of some technical problems in surface exploitation (for example: slope stability analysis), design of the system operation (drilling and blasting, truck transportation, loading and transport) and others.

3. MINING COMPUTER PROGRAM - RRP

Today in the mining industry many computer programs are used that are tailored to the specific needs of mining activity. The database is set on site www.infomine.com, where the professional RRP are classified (<http://www.infomine.com>).

3.1. Gemcom

Software package **Gemcom** is designed for geological interpretation and modeling of unstratified deposits and the design of surface and underground mining of metals and nonmetals (<http://www.gemcomsoftware.com>).

Surpac is a computer program widely used in the global mining practice. It is used for the design solutions of surface and underground exploitation, with the presentation of exploration works. To work in the program it is necessary to create a database and update it during the unfolding of the process of exploitation. Input data from the database are used to generate computational models in 2D or 3D (Figure 1).

Surpac contains tools for data management, geostatistics, modeling, analysing computer model, defining the quantity and quality of deposits, planning of the ore body exploitation by using different types of computer models, production control and automation of certain processes of exploitation (<http://www.gemcomsoftware.com>).

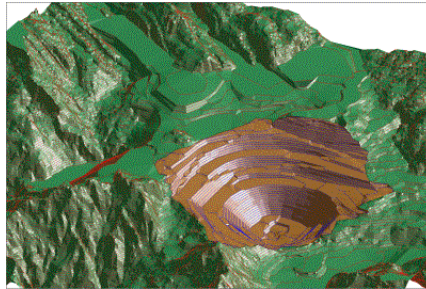


Figure 1 - 3D computer model of surface mine in *Surpac*

GEMS computer program is used for exploration, modeling, design of surface and underground mining operations, long-term planning and monitoring of production (Figure 2). The central database of the computer program GEMS includes data from the following categories: drilling and blasting, the controlled estimated value, geotechnical, exploration, quality control of ore, deposit geology, exploitation plan and survey (<http://www.gemcomsoftware.com>).

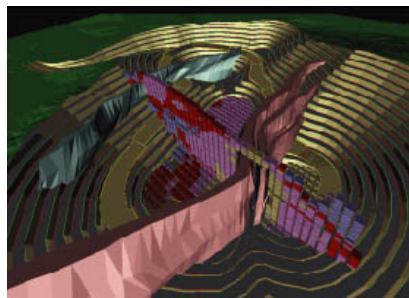


Figure 2 - 3D computer model of the ore body in *GEMS*

Minex computer program is designed to work with stratified deposits, mostly coal. It contains a set of tools for managing geological data and model, classification of stratified deposits, and support for complex geological structure of the deposit. This program allows to connect the databases from exploratory boreholes with a series of geophysical, lithological, hydrological, structural and other data, in order to provide a better description of the ore deposit (Figure 3). The plan of exploitation is closely associated with the geological model. Planning of the exploitation begins by determining the economically most rewarding parts of the deposit which are special marked and followed by a design phase. After creating the project, ore deposit data are stored in a database which can be quickly accessed and make the certain changes (<http://www.gemcomsoftware.com>).

An integral part of the computer program is **Minex Pit Optimiser** which is based on application of Lerchs-Grossmanov algorithm to determine the optimal open-pit contour and this is suitable for a ore deposits with large dip. It is possible to determine the geometry of the pit that is economic feasible to a certain optimum depth,

based on functional dependence of the spread of the final open-pit contour with the depth of the open-pit. In addition to planning the exploitation of Minex provides tools for planning, monitoring productivity as well as tools for the process of mine reclamation and rehabilitation after the exploitation.

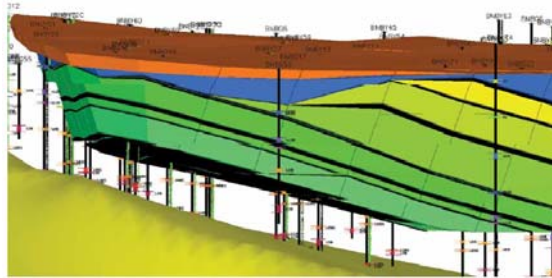


Figure 3 - Overview of stratified deposits in *Minex*

MineSched computer program is designed for process and activity monitoring of surface and underground mining, generating long-term and short-term plans of exploitation. To monitor the excavation process one must have already defined block, computer network or polygon model of the deposit, which represents the input data to the MineSched. After the analysis, processing and comparing data, the results are displayed using appropriate plans and reports that can be supplemented by drawings, 3D animations, diagrams, charts, tables, etc. This software can be interfaced with Microsoft Excel which enables possibility of creating reports and charts, network diagrams and Gantt chart, which allows us to view activity at different time intervals (<http://www.gemcomsoftware.com>).

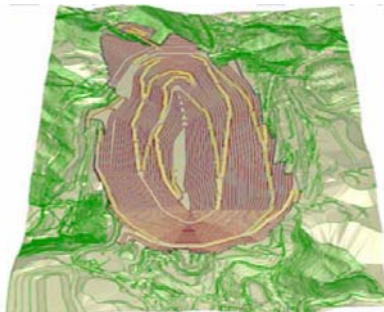


Figure 4 - The final appearance of contour open-pit mine in *Whittle*

Whittle is a computer program originally developed by Australian company Whittle Programming, but today it is a wholly-owned by Gemcom. Whittle is a program for economic optimization of metallic mineral deposits, economic analysis and long-term planning. This programme represent a standard for optimization of open-pit mines, or harmonizing of financial viability and optimal exploitation strategy for the open-pit. This program is used to determine and planning of the life cycle of

open-pit, and for the review of plans during production from the economic analysis on a computer block model (Figure 4). This program combines a wide range of modules for the optimization of open-pit mines: strategic planning, detailed cost and price analysis, landfill design, construction of various contour of open-pit mines, mixed and "cut-off" optimization. In this program LG method is the most successful applied (<http://www.gemcomsoftware.com>).

3.2. RockWare

RockWare company has developed software that can be applied to the following areas: geology, engineering data display and visualization of data from surface and underground mining with a set of program called **RockWorks** and for the geo-mapping with a set of **ArcGIS** software. To create a contour, network and maps in certain areas, for designers is particularly interesting program **Surfer** (<http://www.rockware.com>).

RockWorks includes the following programs: **RockWorks**, **LogPlot** and **RockWorks Utilities**.

RockWorks program is used in mining, geotechnics, oil mining and environmental protection. It is used for visualization and interpretation of data obtained from surface and underground mining. This program can create maps, reports, sections, network diagrams, 3D models and calculations derived from spatial databases (<http://www.rockware.com>).

Program **LogPlot** used only to create and display of geotechnical, geophysical, mining and other data in the form of graphical reports for individual boreholes.

RockWorks Utilities is a set of computer software for mapping, modeling, analysis and presentation that can be used independently or with the RockWorks program. These programs can create contours, 3D surfaces and terrain models, network models, create terrain models and perform calculations of the body volume (<http://www.rockware.com>).

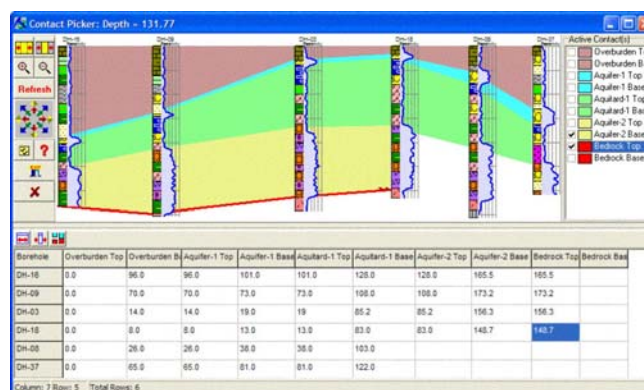


Figure 5 - Ore deposit mapping report from the *RockWorks*

3.3. ESRI

The U.S. company ESRI offers one of the most complete GIS solutions within the **ArcGIS** software collections, which is used for the creation, input, processing, data analysis and display of geographic information in Geographic Information Systems (GIS) (<http://www.esri.com/library/bestpractices/mining.pdf>). **ArcGIS Desktop** software package contains three different licenses: **ArcView®** - basic tools for data analysis and symbolization, **ArcEditor™** - the complex set of tools for editing, symbolization and analysis of spatial data and **ArcInfo®** - includes complex analytic functions (<http://www.arcgis.com>).

Parts of ArcGIS Desktop software package include: ArcReader - basic browser of maps and other GIS products created in ESRI GIS format, using the ArcGIS Publisher. **ArcCatalog™** - allows easy access and management of spatial or geographic data that are stored in folders on local computers or servers available online. Data can be copied, moved, deleted or just reviewed. **ArcMap™** - allows you to create different types of queries and perform a variety of spatial analysis and create maps. **ArcToolbox™** - provides an environment for performing geoprocessing operations (<http://www.arcgis.com>).

GIS provides the right framework for the collection, analysis and interpretation of complex spatial and tabular data as used in mining and geology. GIS connects the layers that contain different information about the position, which allows a better understanding of space. Layers can be combined in different ways depending on the application (Figure 6). Finding the best location to build a new open-pit mine demand connection of different layer (<http://www.esri.com/library/brochures/pdfs/gis-sols-for-mining.pdf>).

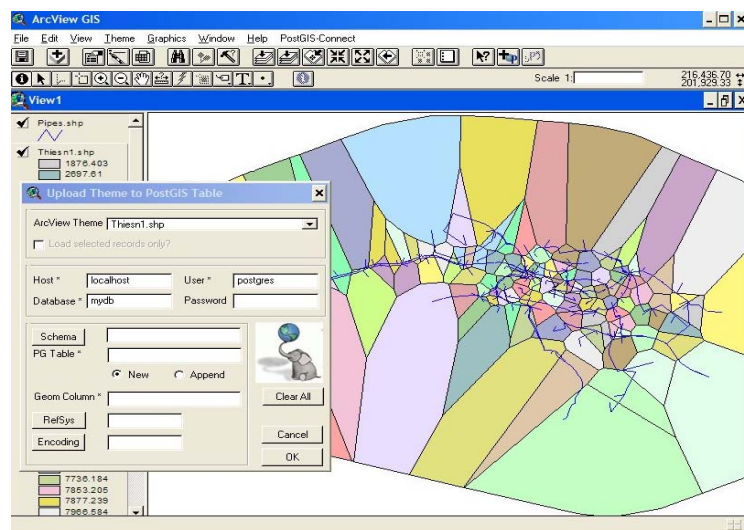


Figure 6 - The layers of the formation of surface mine maps in *ArcView GIS*

3.4. Bentley

MicroStation is a CAD software package for creation of 2D and 3D graphic documentation. The latest version of **MicroStation V8i**, is designed exclusively for Microsoft Windows operating system and includes a completely revised Direct3D - based graphics subsystem, PDF literature, task management and keyboard shortcuts. Visualization capabilities for photo-realistic rendering* and animation are improved (<http://www.bentley.com>).

MicroStation V8 has the ability to load PDF files into your file and dynamically adapt to user needs. MicroStation allows user to prepare the drawings and animation in Adobe PDF format. Users can publish their models directly to *Google Earth*, where you can see models and explore the graphical interactive geographic environment provided by Google Earth program (<http://www.bentley.com>).

3.5. Maptek

A computer program **Vulcan** represents a set of tools for analyzing the ore deposit geology, creating the block model, calculation of reserves, project plan and monitoring of exploitation, and to manage these processes. The software package can be expanded with additional modules to create a database of geodetic surveys, design the mine roads, designing drilling-blasting work, determination of transportation costs based on block models, geomechanical modeling and others. It can connect to ArcGIS software package (<http://www.maptek.com>).

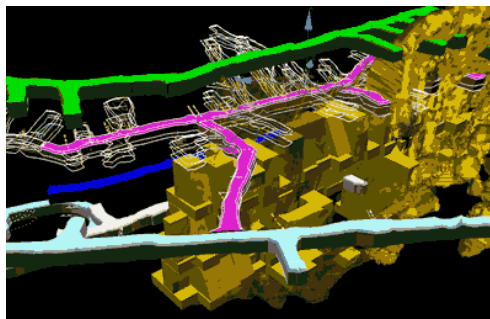


Figure 7 - Modelling of underground facilities in *Vulcan*

MineSuite computer program is a tool for managing and monitoring of the processes in surface mining and underground mining: monitoring of the equipment - *GPS*, *DGPS* and *RF Tag System*, management of the equipment, transportation and production management, surveillance of cyclical transport systems and productivity, equipment fuel management and others. Allows customization of databases in SQL,

* Rendering is the process of converting the model into the image, simulating the transmission of light in order to obtain photo-realistic images.

Oracle and connection to external databases. Generation of different types of reports is possible by conducting analysis of the data (<http://www.maptek.com>).

I-Site technology is used in the exploration, survey, mapping and volume calculations. 3D laser scanner performs the recording and collection of data which are processed and visualized in a computer program *I-Site Studio*. Created computer models allows user to monitor results in parallel to the development of mining operations. Program *I-Site VoidWorks* is used to calculate volume based on data collected in underground mining (<http://www.maptek.com>).

3.6. Mintec

MineSight 3D uses an interactive interface for processing and displaying data from exploratory and blast boreholes, the composite model, the 3D block models, and stratigraphic model of the terrain surface, the survey data of surface and underground works and others. It includes tools for the interpretation of geological data, determining topographic contours, network and triangulation area. This program enables full 3D design of underground mining operations, CAD editing polylines and body sections and 3D spatial objects, features triangulation and visualization of all layers of mining and geological objects (<http://www.minesight.com>).

MineSight Compass can be connected with the program *MineSight 3D*, and can work independently. It is used for the implementation of operations for import, export, composition, interpolation, processing and displaying data from exploratory and blast boreholes, as well as different models (<http://www.minesight.com>).

3.7. Datamine

Datamine is a computer support system designed for surface and underground mining of minerals and raw materials processing industry. This system is developed for managing geological data (Geological Data Management System - *GDMS*) and as system for managing the reserves of mineral raw materials, the development plan of exploitation, design of mining facilities, mining operations management and production monitoring (<http://www.infomine.com/index/suppliers/>).

Datamine Studio 3 is a program for geological modeling, design of mining facilities and management of reserves of mineral raw materials. Provides tools for managing data from exploratory boreholes and samples, maps, laser-captured 3D models and others. It is used for geostatistical and geomechanical analysis and development of computer network and block models. Supports the concept of virtual reality where the geological and mining object model, for example, open-pit mine, can be view as virtual object from the perspective of operators who will operate the equipment, eg. trucks, excavators etc (Figure 8). This concept can made certain improvements in the safety analysis of mining facilities. Geological and mining data can be archived and stored in a file from which user again and again can begin to develop a new variant of the solution (<http://www.infomine.com/index/suppliers/>).

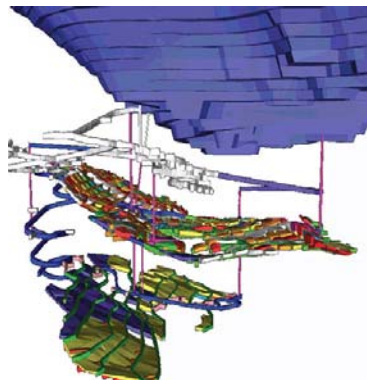


Figure 8 - Model of underground facilities in *Datamine Studio 3*

Underground Mine2-4D is an automated computer program for planning and managing the exploitation of underground mining of mineral deposits, which brings various improvements in compliance with professional mining computer programs such as Datamine, Vulcan, Surpac, Micromine and CAD programs, AutoCAD, MicroStation, etc., connecting directly to a database from which data is automatically updated. Short and long term plans of exploitation, management Gantt associated with 3D models, animations, etc. can be made by this program (<http://www.infomine.com/index/suppliers/>).

Mine2 4D Open-Pit program is designed for surface mineral exploitation, or for open-pit design, planning of the final contours and the process of exploitation of mineral deposits in a controlled natural environment. Optimization of block performed in programs Datamine NPV Scheduler or Whittle. It includes tools for designing open-pit parameters, optimized to work with computer block models, and processes that follows mining operations, such as planning access and transport routes etc. Modules for monitoring of the progress and expansion of open-pit mine allows mine facility 3D animation in which it is possible to monitor changes over time (<http://www.infomine.com/index/suppliers/>).

3.8. Micromine

The computer program **Micromine** integrates modules: *Core*, *Exploration*, *Wireframing*, *Resource Estimation*, *Pit Optimisation*, *Mining*, *Scheduling*, *Surveying* and *Plotting* (<http://www.micromine.com>).

Module *Core* is intended for entry, verification, visualization and interpretation of data from the terrain surface, from boreholes and from underground objects in 3-D programming environment. Module *Exploration* includes a set of tools for statistical calculations, detailed work with data from boreholes and DTM (Digital Terrain Models) areas and networks. *Wireframing* module is used for creating and analyzing 3D surfaces and triangulation bodies. Module *Resource Estimation* incorporates tools for classification, categorization and calculation of deposits. *Pit Optimization* module is used to determine the optimum final open-pit contour using

Lerchs-Grossmanov algorithm. With the *Mining* module develops a blasting plan and parameters that are assumed to show the best results. Module *Scheduling* is used to manage and monitor the progress of mining operations. With the module *Surveying* data from geodetic surveys are entered and processed and the module *Plotting* is used for prepress and printing documents only (Figure 9).

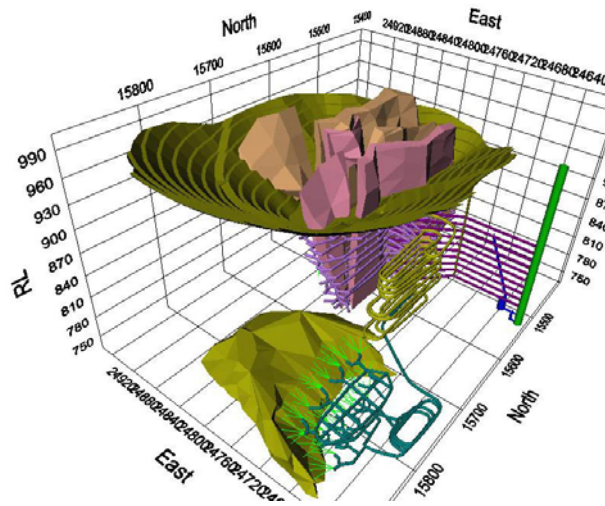


Figure 9 - Computer model in *Micromine*

Field Marshal is used for direct data input and analysis of data collected from geological exploration and mining facilities in the observed exploitation field (<http://www.micromine.com>).

Pitra and **Dome** are computer support for the mining industry for control and management of mining operations through daily, weekly, short and long term planning, collection of relevant data and real-time control, analysis and reporting (<http://www.micromine.com>).

GBIS is a system for managing data and databases, which is based on the following modules: **Core**, **Professional**, **Coal** and **Sample Tracker**. *Core* module is used to build robust data management system that is adaptable to the needs of companies. *Professional* module supplements the *Core* module, and includes tools for working with data from geological exploration and mining activities. *Coal* module is designed to work with complex data from coal deposits, and with the *Sample Tracker* module user can manage collected, prepared and analyzed samples (<http://www.micromine.com>).

3.9. Geosoft

The computer program **Oasis Montaj** is used for analysis, processing, 2D and 3D interpretation of geophysical, geochemical and geological data. By integrating data from terrain surface and data from boreholes, and geophysical models the expert

interpretation is simplified. In the program different types of data can be entered, for example. data at certain points, network and images, vector and 3D data, data from the measuring instruments, GIS data, network and block models and others (<http://www.geosoft.com>).

The program has integrated support for connection to external database servers, and support for creating, viewing and sharing files with other users of ArcGIS. Oasis Montaj is used in the exploration of deposits of mineral resources, geological explorations and mapping, exploration of oil and gas, environmental protection, education and others.

Target computer program is primarily designed for creating and visualizing structures below the terrain surface using data from exploratory boreholes. It includes tools for processing network of exploratory boreholes and geophysical models represented as 2D networks, STR Surpac, Datamine or DTM network models (Figure 10). Data on exploratory boreholes can be entered from different data sources and visualization of these data can be made in the reports on boreholes mapping and network diagrams. By combining data from the terrain surface and from exploratory boreholes can be developed detailed and integrated maps for the surface and underground mining (<http://www.geosoft.com>).

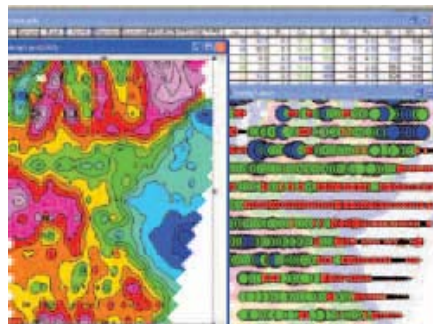


Figure 10 - Creating a network of surfaces and contours in *Geosoft Target*

3.10. AutoDESK

AutoDESK is the founder of the industry standard for 2D and 3D technical design and modeling. **AutoCAD** is a computer program that belongs to the group of CAD program and does not belong to a group of professional mining programs, but is used in mining for technical documentation. In addition to mining AutoCAD is used in civil engineering, architecture, mechanical engineering, electrical engineering and other fields, with specially adapted versions for each area. For the preparation of technical documentation in AutoCAD this program is using the tools for organizing and managing drawings formats and scale, blocks of commands to automate repetitive processes, drawing from specifying parameters and others. Work in 3D programming environment is supported by the tools for modeling 3D objects, visualization, navigation and input laser scanned objects in the 3D environment (<http://usa.autodesk.com>).

4. COMPUTER MODELS OF ORE DEPOSITS AND MINING FACILITIES

Under construction of ore deposit computer model or group of ore deposit computer models and mining facilities it is possible to use five types of models. These models generally use the same input data but have different output formats. Each of the types of models which are in use, has its place and role depending on the model application.

4.1. Triangulation model

Triangulation is the initial step for the development of network and contour models in most of the RRP. This model consists of a series of triangles formed on the basis of reference points (boreholes). Triangulation is used to represent the terrain surface, roof layer or sublayer, the ore body, open-pit mine etc (Figure 11).

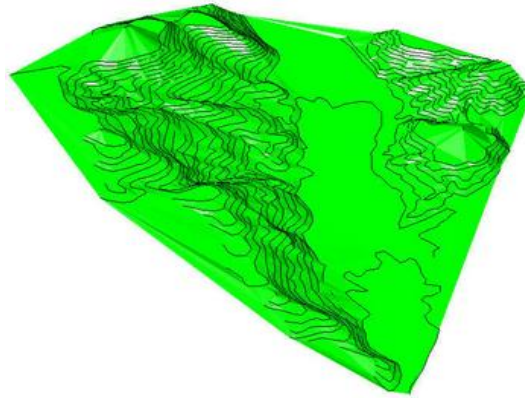


Figure 11 - Triangulation model bearing in *AutoCAD*

4.2. Network - digital model

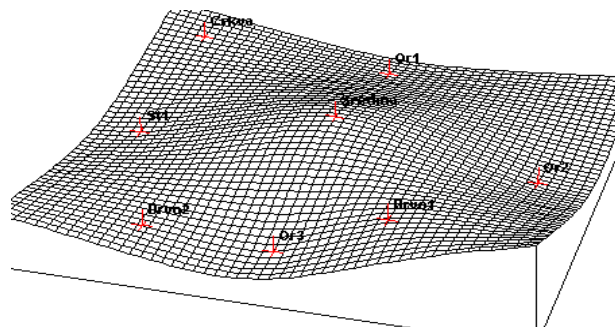
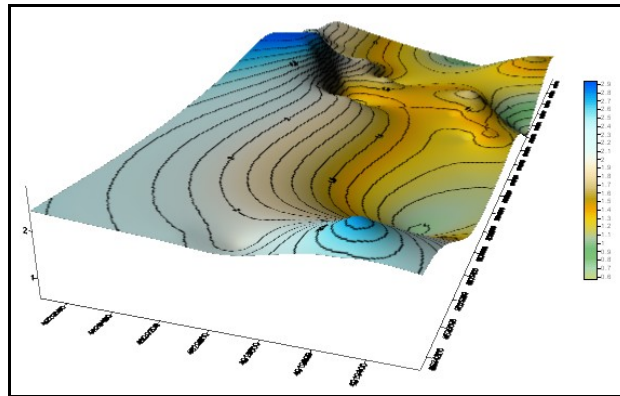


Figure 12 - Overview of network models bearing

The network model is a series of lines or strings which are mostly used to limit the area, similar to the triangulation. It can be run as a surface (for example, in the direction of x and z axes) and spatial model (in the direction of all three axes). Network elements can be a rectangle (square) or other, such as the network model of the topography of the terrain (Figure 12).

4.3. Contour Model

Contour model can represent different types and parameter values. In the process of developing a computer model contour model is usually used in combination with the network model or by itself, with 2D or 3D views. Contour model is particularly suitable for displaying plans in two dimensions, as well as for the network model which the quality of outputs depends on the density of the network (Figure 13).



Slika 13 - Contour model of the bearing shown in *Surfer*

4.4. Wired model

Wired model defines the spatial shape of the object being modeled (Figure 14). It is based on the application of interactive parameters and their relationships in the model. This model can represent the ore bodies, faults, rooms in mines with underground mining and so on. It can be analyzed in the isometric view, also in combination with other models. It can be converted into a block model. To enter the data it is necessary to know the goal of making wire model, and on that base input parameters are determined (the size of the ore deposit, the length of the tunnel, etc.).

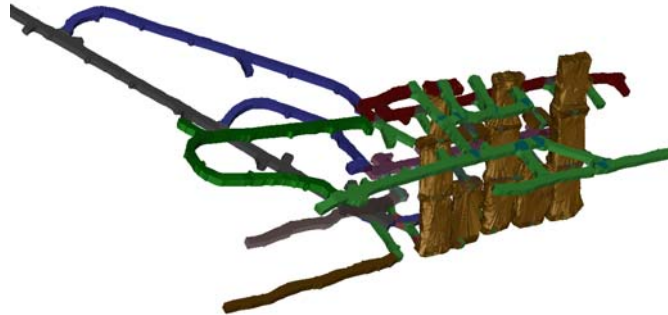


Figure 14 - Wire model of underground facilities in *GEMS*

4.5. Block model

Block model is used to define a ore deposit model or open-pit mine with the division into the 3D blocks and sub-blocks (Figure 15). This model can represent the geological structure of the ore deposit, distribution of zones of mineralization etc. Block model is define by a method of interpolation, statistical or geostatistical methods and closest neighboring points method, and can be viewed in the plane, cross-section, or 3D shape. Block model provides the greatest opportunities of all types of models and therefore has the widest application in modeling ore deposits and open-pits. It can be used for all types of deposits by adjusting the dimensions of blocks.

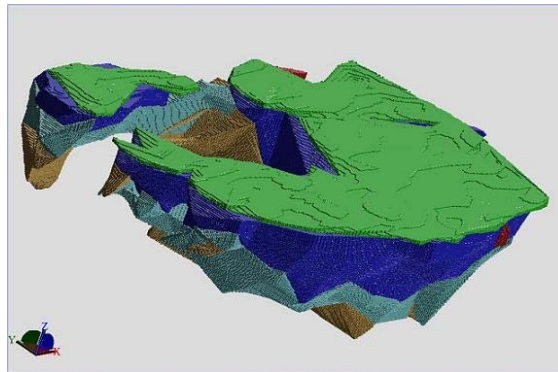


Figure 15 - Block model of the bearing shown using *Surpac*

5. CONCLUSION

Information technologies are applied in mining for design and modeling of surface and underground mining in order to reduce production costs and preparation time and increase productivity.

With the help of computer programs, which are based on 3D graphical interface, enables the efficient management of the process of optimization of surface

and underground mining through the process of digitizing, vector rendering and visualization in real time. The basis of program are the tools for creating 3D structural model.

Computer software packages provide the ability to identify and obtain data on mineral resources which are of the greatest importance for optimize and the homogenization of processes in mining. Graphical representation of the computer programs have contributed to more efficient and qualitative approach to planning, modeling and optimization of production and mineral resources processing.

Computer programs for surface mining and/or underground mining modeling, as well for the production planning, represent the basis for process management and design tool for mining activities.

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