

Design and Visualisation of Underground Workings Using Information from Multiple Sources

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ABSTRACT

Major underground projects today require integration of information from various sources in order to achieve high engineering standards and adhere with strict safety and environmental legislation. Such information may include underground designs, groundwater models, geotechnical data and models, laser scans, digital photography, models of existing openings, land surface data and models, and geological information. Computer hardware and software systems currently available provide a comprehensive environment for the development of underground projects facilitating the advanced visualisation capabilities offered by these systems. This paper covers a number of modern techniques and methodologies used in visualisation of underground workings, integrating information from multiple sources. The design procedures described are tailored both for the production of construction plans for plotting purposes, and also to produce uniquely named construction blocks for project scheduling. The modelling procedures covered in this paper can help achieve realistic visualisation results while maintaining engineering accuracy and content. The advanced level of visualisation achieved enables better communication of ideas, concepts, problems and solutions between people from different backgrounds and levels of computer literacy. Integration of all possible data sources in a single visualisation environment also enables better assessment of risk during construction and later in the life of an underground project.

1. INTRODUCTION

Conventional project assessment and planning systems have for the most part been limited to conventional output forms, directly related to manual methods. These forms, being the maps and plans created by draftsmen, have formed in the past an adequate basis for the presentation of this information. However, contour maps and cross-sections have become a very limited platform for proper assessment of planning data. Rapid assessment and dissemination of information and the need for proper simulation of events has created a need for the use of visualisation in underground projects (Johnson, 1984).

The increased availability of geoscience information and data in digital form and major improvements in information technology have had a significant impact on the procedures used by mining and geotechnical companies for mineral exploration, mine planning and major underground projects. The application of advanced information technology using a GIS platform linked to a knowledge-based mapping system offers considerable potential for underground mining projects and geotechnical works. Several hardware and software packages exist today for data acquisition and data processing and modelling that enable advanced visualisation and communication of information and data from underground projects. In this paper, Vulcan 3D software (Maptek Pty Ltd) is used to illustrate design, modelling and visualisation procedures for underground projects.

2. UNDERGROUND DESIGN AND AS-BUILT MODELLING

2.1 Conceptual Underground Design and Modelling

Along with many different objectives possible in underground design and modelling, the areas of focus can also vary widely. Some general areas of focus include the development and production processes, supporting processes, and material handling. A general mine planning software package commonly hosts a number of underground development design options for laying out declines, crosscuts, ore/waste passes, boreholes, motorbarns, shafts, etc. Powerful options allow querying the resulting objects for their volume, tons, length, cost, time to complete, etc. Stope design options can be used for drawing stope outlines at any orientation. As the outlines are drawn, the view is automatically advanced and a solid triangulation is built between the drawn stope outlines. At any time during this design process, one can query an existing block model for reserves over the entire stope being created or just for the last advance. Underground blast options are used for creating ring blast designs. They allow for downhole and uphole drilling, drilling inside the stope or drilling anywhere around the stope. Reports on hole locations and orientations can be plotted alongside a view of the blast pattern.

Modelling of underground designs can be performed either by standard solid triangulations between roof and floor polylines or by using primitive sections and centrelines of different parts of the design. The generated models can be split into development and production units using shelling modelling functions that also name the models using their location, distance from a line, or sequence for identification purposes. This feature is very important when reserving and scheduling.

2.2 As-built Modelling

Underground mapping commonly takes place using specially designed equipment based on platforms or carried by trained personnel. A wide variety of construction monitoring and as-built records can be acquired as part of the normal monitoring of the construction performance against the design. Most of this data is integrated with scientific data as it is an element of the physical and temporal context of the scientific data. Data is acquired on hydrostatic linings, rock bolts, sprayed concrete, ventilation, grouting, probe drilling, shaft profile, and blasting. The survey of the works forms the spatial framework upon which other information is located.

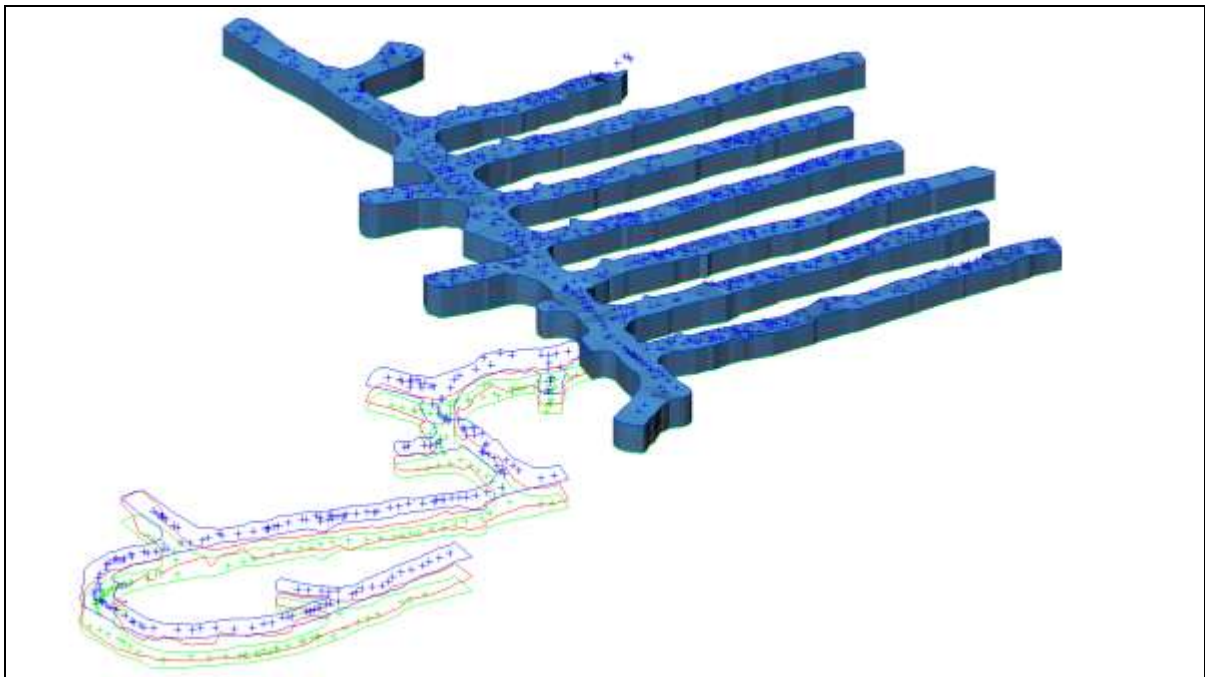


Figure 1: Survey data and as-built model of underground development.

As-built models of produced underground openings can be generated and compared against conceptual designs using a number of modelling methods. The selection of method depends on the spatial distribution of points, which in turn depends mostly on the data acquisition method. Vulcan can generate solid triangulation models from surveyed lines and points using two main algorithms: the standard solid triangulation and the AutoModel algorithm. The standard triangulation method links points between closed or open polylines in order to close the surface between them. This is particularly useful when modelling the walls of underground openings. Surveyed points on the roof and floor can be used in conjunction with the standard Delaunay surface triangulation algorithm to generate the roof and floor caps of the model and, thus, close the solid model (Figure 1). The AutoModel algorithm inflates or deflates an imaginary surface built from Radial Basis Functions (cubic or thin plate spline) to match all available vector data or other triangulations.

3. UNDERGROUND LASER SCANNING

3.1 Equipment

Laser scanners are ground based survey instruments capable of acquiring many thousands of points per second and high resolution panoramic photography. One of the most advanced laser scanning instruments available today is the I-SiTE 4400 scanner, an instrument capable of acquiring 3D points in a 360° sweep up to a distance of 1000 feet (Figure 2). The I-SiTE 4400 Laser Imaging System is a combination of several technologies integrated in a single instrument. It can be used to acquire 600,000 points in 3D in less than 3 minutes. It is a portable instrument that is easy to setup and capable of performing multiple survey tasks from one vantage point. Field control of the scanner is achieved by a dedicated hand held controller (HHC) with site survey control software (Figure 3). Scans are located automatically. The scanner is accurately levelled by an automatic digital level compensator (20"). Its rechargeable battery life is more than three hours, while it takes about one hour to recharge. The scanner's panoramic high resolution digital camera (37 mega pixels) can capture a 360° by 80° image in 10 seconds. Digital photographs can be exported in JPEG format. An optical telescope is controlled by a stepper motor that allows defining the direction of the scan. Potential field of view is 360° horizontal and 80° vertical – the same as the digital camera on-board the scanner. The scanner field of view can be controlled from the HHC or a remote control. The point cloud captured by scanner has coordinates relative to the origin of the laser, therefore, in order to accurately locate a scan it is necessary to provide the instrument altitude, the coordinates of the scanner and backsight coordinates.



Figure 2: Front and rear view of I-SiTE scanner (left and middle) and scanner in action underground.

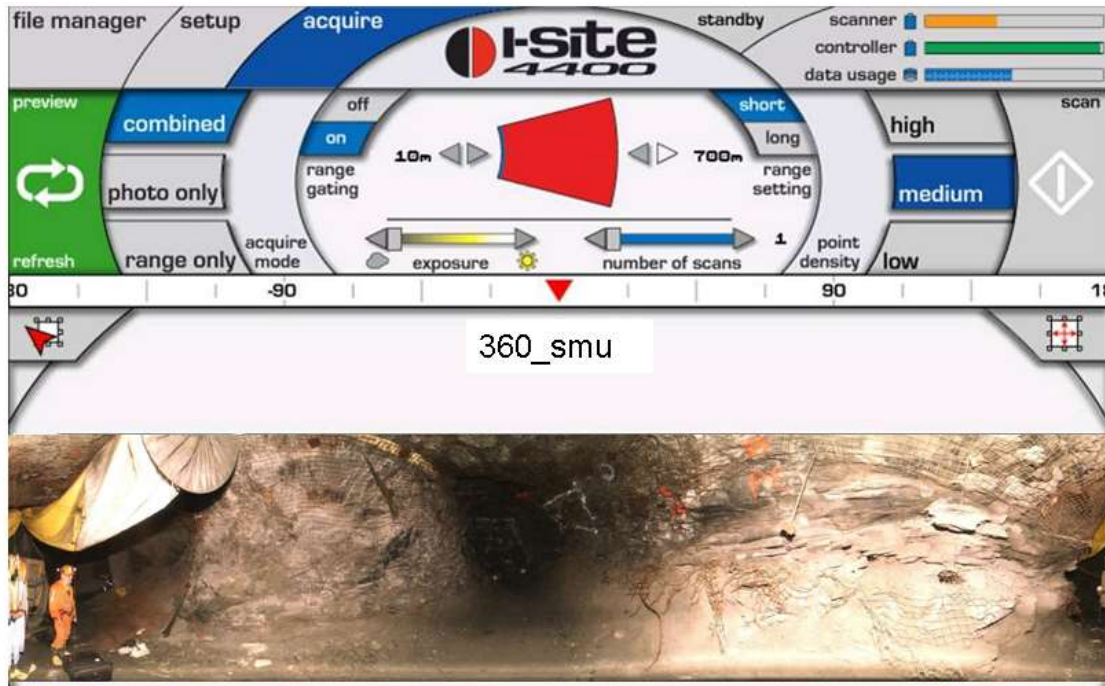


Figure 3: I-SiTE hand held controller screenshot showing panoramic image of underground openings.

3.2 Modelling Laser Data

The cloud of 3D points from a laser scanner can be fairly difficult to model using standard triangulation modelling methods. Modelling can take place both in Vulcan and in I-SiTE Studio – a dedicated data processing and modelling package available with the scanner. As points from a single scan are taken from a central point where the scanner was located, Vulcan performs a transformation of data using polar coordinates, applies the Delaunay algorithm on the projected data and then brings the model back on the original coordinate system. This operation can be used to produce the triangulation model of a single scan. Multiple models can then be combined using Boolean operations or the more recent AutoModel function to form a single closed solid model (Figure 4).

4. SIMULATION AND VISUALISATION OF GROUNDWATER FLOW

4.1 Groundwater Modelling

The understanding of groundwater systems is a vital step in most environmental engineering projects, where this can be used to model contaminant pathways and to identify potential water resources. The development of conceptual hydrogeological models is usually based on the same geological information as used for geotechnical evaluation, site investigation and delineation of geological features. Vulcan can incorporate observed hydrogeological data to interface to MODFLOW and Aquifem-N flow codes, improving the accuracy and confidence of the groundwater evaluation process (Neilson et al., 2000). The tools provided enable a number of modelling processes incorporated in the groundwater analysis. Specifically, Vulcan can perform the following tasks:

- Create graphical representations of conceptual hydrogeological models
- Display the extent and flow of aquifers in 2D and 3D
- Allow transport modelling of potentially hazardous pathways
- Integrate topographic, geological and survey information with hydrogeological data
- Support 3D finite difference and quasi 3D finite element codes

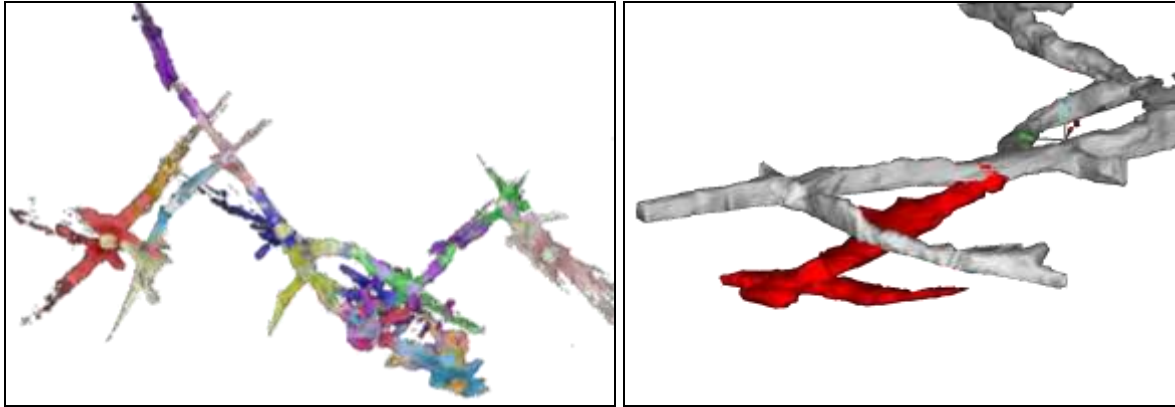


Figure 4: 3D points from multiple scans underground (left) and solid triangulation models (right) generated in Vulcan.

4.2 Fracture Network Modelling

Groundwater flow and solute transport in fractured rocks are dominated by small scale discrete flowing fractures, as well as large geological structures such as faults. In an integrated software environment such as Vulcan, it is possible to perform discontinuity data analysis, and simulation and visualisation of discrete fracture networks (Wei et al., 1996). The generated fractures are represented as triangular finite elements for flow and transport calculations using a flow solver. Vulcan is used to display in three dimensions the fracture networks, animate the calculated flow field, or calculate and display local and regional head contours (Figure 5). It can also display and animate the simulated particle transport movements and analyse network properties anywhere in the network.

5. GEOTECHNICAL DATA AND ANALYSIS

Geotechnical data acquired on-site can be used to produce a geotechnical (structural) database. The structural data is represented as objects according to structure type (Table 1). Each structure is coloured according to the value for nominated fields in the structural database. The data can be displayed either in a 3D window together with other data and models (Figure 6), in a stereonet projection view, as a rose diagram, or be used to perform interactive interpretation and analysis. Options are available for updating existing structural data or adding new structural data to the structural database. For example, structural data may have already been entered into the structural database, but without co-ordinate information. The co-ordinate information can be digitised based on the surveyed locations and the relevant structural data records updated. New face mapping data can be easily appended to the structural database by digitising the locational information and entering the associated structural data.

Table 1: Structural data fields stored in database.

| Name | Description | Example values |
|--------|---|-----------------|
| AMGEST | Easting | 232115.6 |
| AMGNTH | Northing | 34561.2 |
| ELEV | Elevation | 345.4 |
| DIP | Dip | 35, 12, 9 |
| DIPDIR | Dip Direction | 327, 139, 90 |
| TYPE | Structure type (a maximum of 10 characters) | F, JNT, BDNG, S |

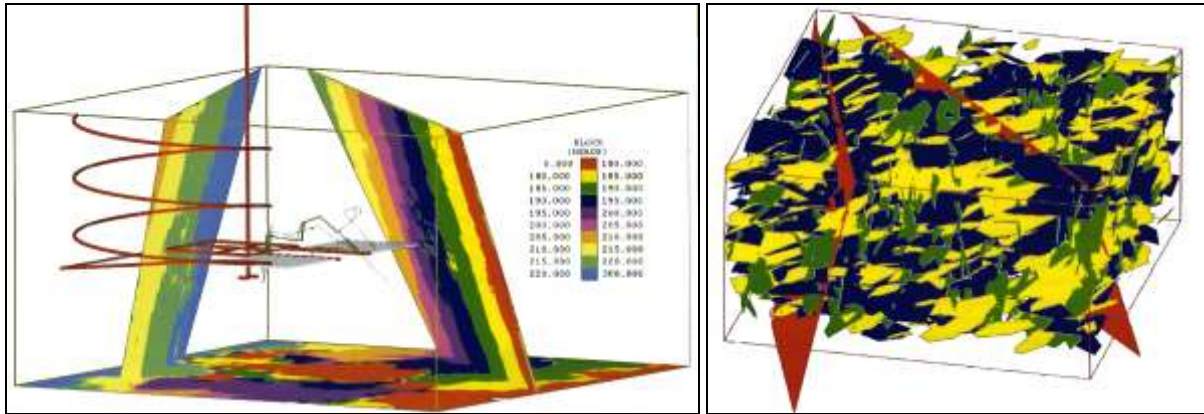


Figure 5: Groundwater head variation across a potential waste repository (left) and display of discrete fracture networks and faults (right).

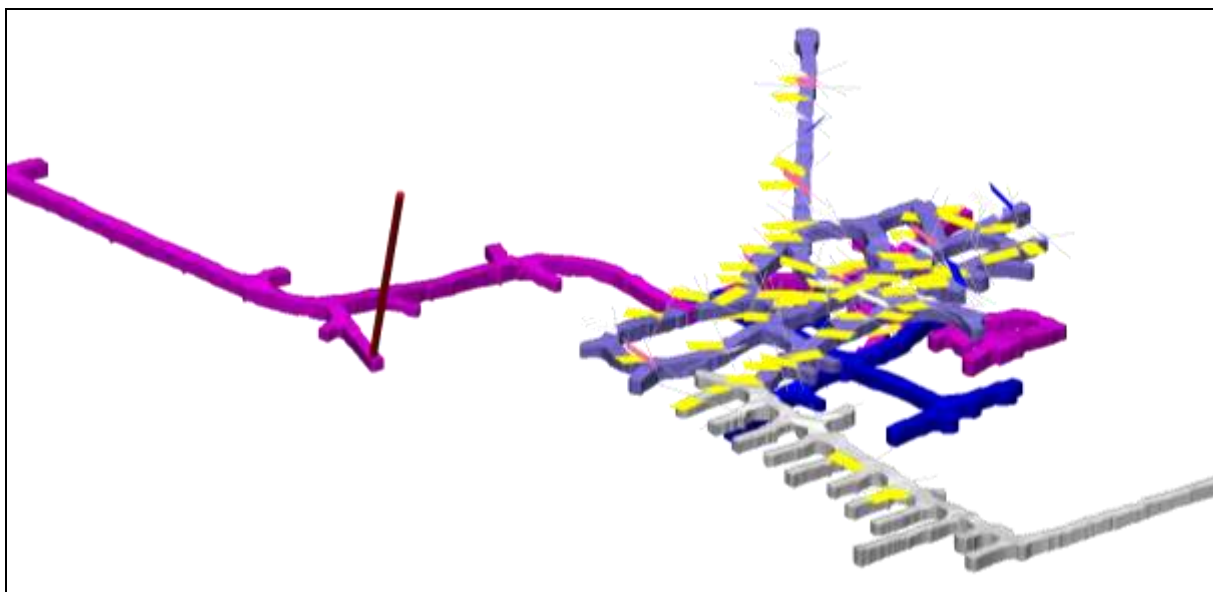


Figure 6: 3D display of underground as-built models and geotechnical data.

6. CONCLUSIONS

This paper has shown some of the main areas of application of dedicated software and hardware in the field of underground design and modelling. The benefits of using the functionality and graphical capabilities of these systems have been demonstrated through various examples in areas related to the design, construction and monitoring of underground openings. The integration of different types of graphical and numerical information in a single graphical environment enables engineers and other scientists to gain better understanding of the particular problem and reach the best solution.

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