Managing the mining cycle using GeoVisionary

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ABSTRACT

Managing the mining cycle from exploration through to evaluation, planning, construction, operation and finally mine closure can involve many datasets in different formats. To be able to visualise all of these different datasets in one environment is important to locate mineral/ore deposits, moderate risks, increase mining efficiency, monitor the impact on the surrounding environment and communicate these factors to stakeholders. Typically, GIS – Geographical Information Systems have been used to manage the life cycle of a mine, however the three dimensional (3D) complexity is lost in these two dimensional (2D) systems. Virtalis alongside the British Geological Survey, have developed the GeoVisionary software which provides the means to aid the management of many aspects of the life cycle of a mine using a combination 2D, 3D and 4D data in the same virtual environment.

Introduction

Digital capture, modeling and visualization of data from the natural and built environment have improved significantly over the last 15 years. This improvement has been partly down to the use of hand held devices such as mobile phones and tablets, and the software applications that support them (Westhead et al, 2013) and partly down to the use of Virtual Reality (VR) software and hardware that enables the user to immerse themselves within 3D geoscience datasets (Napier, 2011). This in turn has increased the efficiency in which geospatial data is captured, analyzed and disseminated.

The mining cycle lends itself to many of these technological advancements as many stages of the cycle can be augmented by VR software which in turn saves resources, mitigates against potential hazards/dangers (Mark, 1998, Mallett, 2007) and provide a platform that allows the user of these systems to analyze relationships between 2D, 3D and 4D data. Not only have these VR systems significantly improved the understanding of geospatial data for geoscientists, these systems have played a pivotal role for communicating geospatial data to non-geoscientists, who tend to be the key stakeholders regarding the permissions needed to set up a mine. VR systems help these stakeholders grasp the meaning of the data and information provided to them. In mining terms, this may allay fears over on the potential impact on the environment and could speed up the planning permissions required and the general development of a mine.

To put this into perspective, mineral exploration can be augmented by virtual field mapping using VR systems which would allow the user to explore areas that are difficult to reach by land, save resources by analyzing remotely sensed data and help target areas which might be of interest for the for extraction, potential transport corridors and base camp locations. Traditional desktop studies before and after exploration are worked-up using 2D-GIS systems, however much of the data is captured and attained is in 3D, therefore visualizing all of the different types of data together in its correct spatial position gives the user a greater understanding of the relationships between geospatial datasets and the limitations of those data (Mark, 1998). To fully appreciate and understand the geospatial data for mining, the user must be able to visualize several 2D, 3D and 4D datasets together which includes but are not exclusive to the following:

- Geological data including maps, coal seams, faults, dykes and joints
- Boreholes – vertical and deviated
- Geological cross-sections and modeled surfaces
- 3D geological models
- 2D and 3D geophysical surveys
- Chemical data – soil and water
- Mapped data capture such as bedrock dips and strikes
- Parameterized volume models showing geotechnical and geophysical properties
- Digital Terrain Models and LiDAR (including quarry and mine laser scan data)
- Imagery including aerial photographs, satellite images and topological maps
- Human infrastructure including buildings, utilities and mine plans
- Natural objects including trees and hedges
- Animations of vehicle and equipment movement

Very few software are able to visualize and interrogate all of these disparate data types in one VR environment whilst retaining the full resolution of the geospatial dataset. Virtalis with the BGS have developed the GeoVisionary software for exactly for this purpose.

GeoVisionary

GeoVisionary is the result of a lengthy research collaboration between the British Geological Survey (BGS) and Virtalis. It is a unique 3D stereographic software system that was initially developed specifically for virtual field reconnaissance, that allows the high-resolution visualisation of geospatial data that is generally used for mapping and geospatial data interrogation, from sub-continental regions to site specific areas with the only limitation being that of the data itself. Although primarlily a visualization package, specific tools have been developed in GeoVisionary that are useful for landscape feature interpretation. These include digitisation in 3D space, terrain and plane measuring tools for dip angles, gradients and lengths (Figure 1), and light manipulation to enhance features in the landscape.

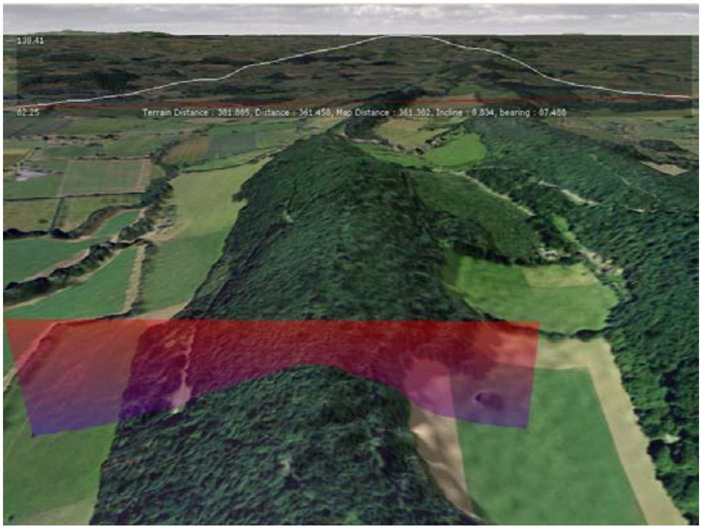

Figure 1: Terrain profile in GeoVisionary showing inclination and length

GeoVisionary has been developed to link seamlessly with digital mobile mapping software such as SIGMA mobile (Jordan, 2009). ArcGIS link tools allow the user to ingest and display results from the field mapping in GeoVisionary and vice versa on the fly.

By using both the VR and mobile mapping systems together, the geologist is able to map an area more quickly and comprehensively then when using older analogue techniques for mapping and exploration. Observations are captured more efficiently digitally, issues can be reconciled in historical and current geological maps when displayed digitally with other data, and the geologist is able to review their own linework captured in the field with other geospatial data in a VR environment. This approach has been used extensively in the UK and overseas in such places as the USA, UAE and Tajikistan (Bateson et al, 2009).

Further development of GeoVisionary has focussed on the integration of 3D and 4D data such as 3D geological model data including boreholes (both vertical and deviated), cross-sections and surfaces as well as parameterized voxel models (Figure 2), LiDAR point cloud scans, CAD models of buildings and infrastructure, and time series data that for example could show land level change or water table variation.

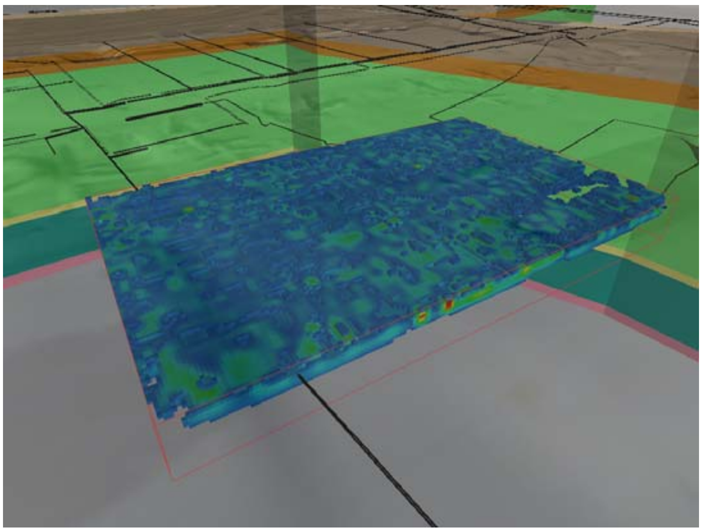

Figure 2: Voxel model showing density integrated with utility data in GeoVisionary

Therefore GeoVisionary is used for more than virtual field reconnaisance and exploration, as it can be used but for planning, analysis, communication and dissemination of a large variety of geospatial data. These datasets could be drawn from GIS such as ESRI or MapInfo, 3D Modelling packages such as GOCAD and PETREL, and CAD modelling software such as Bentley Microstation or AutoCAD.

How the mining cycle is managed using GeoVisionary

Managing the mining cycle from exploration through to evaluation, planning, construction, operation and finally mine closure can involve many datasets in different formats. To be able to visualise all of these different datasets in one environment is important to locate mineral/ore deposits, moderate risks, increase mining efficiency, monitor the impact on the surrounding environment and communicate these factors to stakeholders. GeoVisionary can augment the mangement of many of these stages in the mining cycle.

Exploration, Evaluation and Planning

GeoVisionary was initially developed for Virtual Field Reconnaissance for geological mapping (Napier, 2011) therefore many of tools and links to other software have already been established with regards to mineral exploration. This approach of using mobile mapping software in tandem with GeoVisionary has been successfully implemented in Brazil by Vale Mining and Coffey Ltd in the Minas Gerais, near Belo Horizonte in Brazil (Procópio et al, 2014). They noticed an improved performance in three separate phases of exploration which included:

1. Pre-Fieldwork – Geospatial data was compiled into GeoVisionary which included shapefiles, high-resolution images, geological maps and DTMs. These data were analysed through photo interpretation techniques and data analyses of several geospatial datasets in order to identify the geotechnical characteristics that are present, and establish the objectives of the fieldwork campaign. The main benefits were being able to visualize a huge range of data at ultra-high resolution, team participation and discussion, ease in the interpretation of new routes and checking critical points such as morphology of the ground facilitating the identification of areas safer to conduct fieldwork (Figure 3).

Figure 3: Immersive 3D Visualisation Facility

2. Fieldwork – A GeoDatabase containing the data and results of the pre-field study phase was transferred into the SIGMA *mobile* application on a ruggedized tough book/tablet with an integrated GPS and camera. This enabled real-time visualization of the study area, plus the capability of consulting and interpreting data on the fly. The standardised digital data capture in the field meant that errors in recording data decreased and was captured efficiently in a format which could be directly imported into GeoVisionary (Figures 4 and 5).

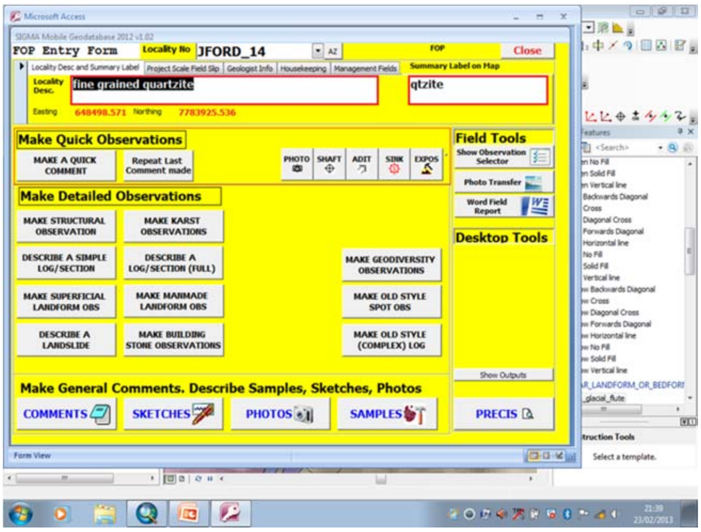

Figure 4: Example of data interface for SIGMA *Mobile*

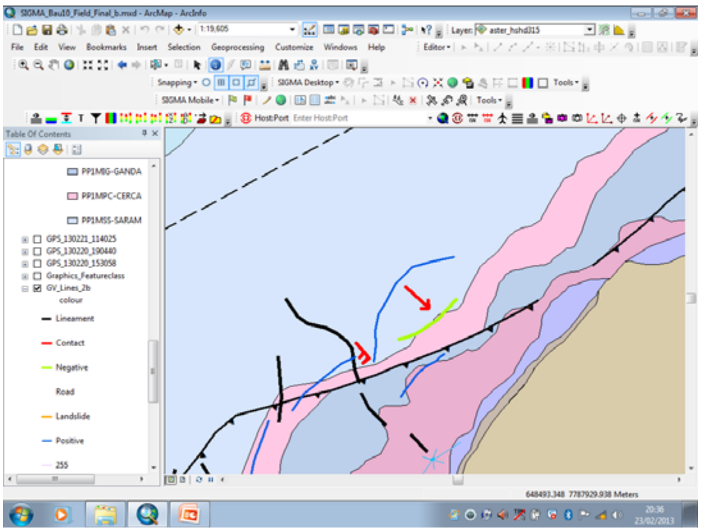

Figure 5: Data annotation in SIGMA *Mobile*

3. Post-Fieldwork and evaluation – Data acquired is discussed and reviewed against other geospatial data as a group in the VR environment using GeoVisionary. From this exploration phase, the mineral ore can be evaluated in GeoVisionary using a variety of geospatial data. These can include geophysical surveys, boreholes and

voxel models as shown in Figure 6 which shows a density model of an ore deposit with vertical and non-vertical boreholes.

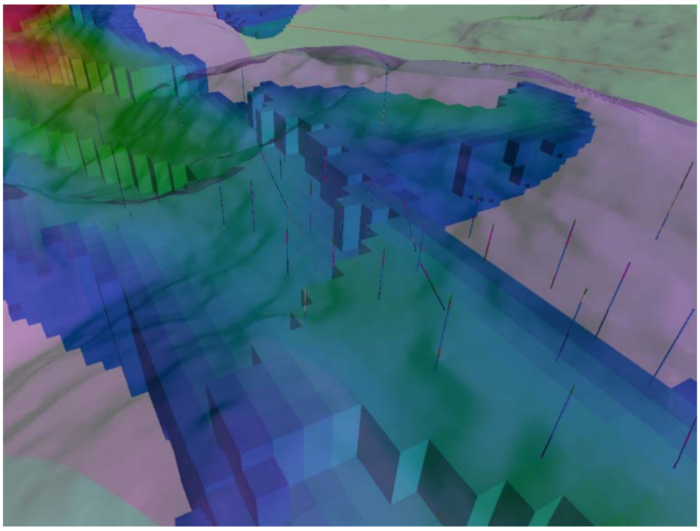

Figure 6: Voxel model of rock density with boreholes

Planning, Construction and Operation

As mentioned previously, GeoVisionary provides the ability to visualize a wide variety of 2D, 3D and 4D data in a VR environment, which in turn allows the users of this data to see previously obscure dataset relationships. In planning terms, this means that potentially difficult mining conditions can be avoided, for example where there are complex structural issues that occur around faults and joints (Leblanc, 1997).

Furthermore, GeoVisionary can be used to communicate to miners and those working on site the dangers and potential hazards during construction and operation (Mallet, 2007). One method is using the VR system to show moving objects such as trucks and equipment (Figure 7) and the likely paths they are to take which can simulated in GeoVisionary by using pre-constructed lines of path and in the future using GPS to show the live location of these vehicles. This means the user is able to manage the safety of mine remotely in many situations, and enhance the communication of instructions more effectively to the mine workers.

Figure 7: Mining equipment models from CAD in the GeoVisionary workspace.

Mine Closure

Part of the process of mine closure in the modern world is being able to demonstrate that the site will not pose a threat to the health of the environment or society in the future. Depending on the site, the mine may be repurposed for other human uses or re-stored to its pre-mining use following closure. Typically, this involves several steps which include shut-down, decommissioning, remediation/reclamation and post-closure. As in mine operation phase, GeoVisionary can be of use in all of these steps. For example, in the shut-down and decommissioning phases, GeoVisionary can be used to locate assets that need removing such as mining equipment and for other assets such as buildings, it can be used to plan the demolition or repurposing of these.

In the remediation/reclamation phase, GeoVisionary can be used to demonstrate pre-mine visualizations of the landscape against post-mine visualizations of the landscape to stakeholders and the public. This can be also done in the planning phase of the mine to obtain the necessary permits. These visualizations could include how the land will be reshaped, the locations of the replanting of native grasses, trees or ground cover, and showing the chemistry of water courses to see if they are at an acceptable standard. During the Post-Closure phase, often monitoring programs are implemented to assess the effectiveness of the reclamation measures, and occasionally they may need additional long-term care and maintenance after mine closure such as ongoing treatment of mine discharge water, periodic monitoring and maintenance of tailings containment structures, and monitoring any ongoing remediation technologies used such as constructed wetlands. GeoVisionary has the capability for live monitoring of environmental data as shown by ANDRA (Mangeot, 2012). ANDRA, the French National Radioactive Waste Management Agency, use GeoVisionary as an umbrella 3D visualization system for data from various sources principally ANDRA's Geodatabase, which holds samples, geoscientific data and SAGD, a database which holds all the real-time experimental data collected from thousands of sensors in numerous drifts and boreholes. These sensors and samples can be queried using URLs to live link to the database. The locations of these sensors and samples can be visualised with the Underground Research Facility (490 m below ground level) alongside other geological data such as horizons and cross-sections (Figure 8). This has proven that GeoVisionary can be used to facilitate the analysis and monitoring of the environment long-term and be used as a communication tool to stakeholders including the local population and authorities.

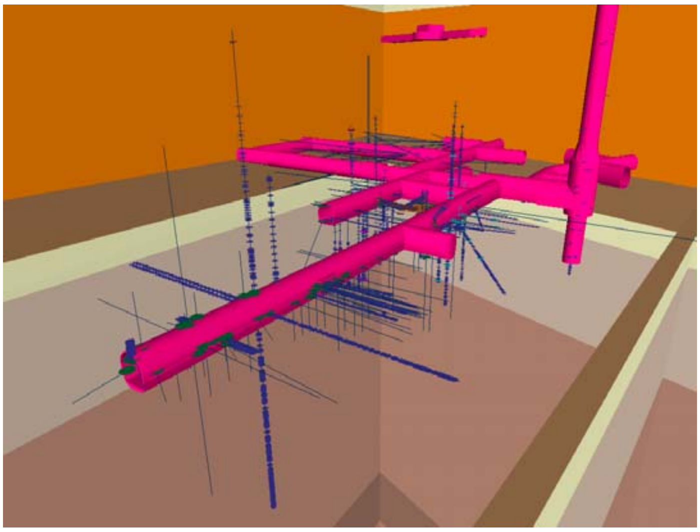

Figure 8: Underground rearch laboratory with sensors and geological cross-sections

Future developments

As of 2015, GeoVisionary will have an interface overhaul and have many new features that will further aid the management of the mining cycle. A summary of these features are below:

Web Feature Service (WFS) - This will allow the manipulation and editing of geographical vector features over a web interface and allow any application that can work with web services access the geographic information stored in the map or in the geographic database. Key decisions regarding safety and areas in which to extract could be achieved more quickly and efficiently using web services as a provider of vector information.

GeoVisionary Conferencing Module – this is a module for communicating GeoVisionary projects over a network or the internet to any device capable of receiving a video stream. A high speed video stream with very little lag allows the GeoVisionary 'pilot' to display projects to those without a GeoVisionary license. The streaming technology developed by Virtalis Ltd also allows stereoscopic image transmission for suitably equipped receivers. Geospatial objects can be interrogated and manipulated in 3D space and means that users that could be working remotely from one another can work and visualize data on the same project together at the same time. For example it would mean that a user who was managing the overall mining project could present and manipulate data in 3D space from their office to onsite workers a few miles away to enable the clear communication of instructions.

Live sensor output visualization – Presently, sensors can be accessed through URLs in GeoVisionary, however this will be improved to enable objects to provide live information from sensors in the real world through a web service. This will include information such as when data was collected. These data can be further manipulated in GeoVisionary as interpolated maps can be produced from the sensor points using nearest neighbor or Inverse Distance Weighting. This means that patterns and trends can be analyzed more easily from the results of the live sensor data and these outputs are updated on the fly automating the procedure for assessing the data. For example, this could be analysis of water chemistry before, during and after flooding events.

GPS Tracking – At present GeoVisionary visualizes the motion of objects on predetermined routes or uses times series data to show motion in the natural environment. Live tracking of motion from sensors will automate this, as the user will be able to read the data placement of one or more points and show them in virtual reality interface. Movements will be able to be tracked in the immersive environment and will have an impact on the operation and safety of a mine.

All of these new features will further enhance the use of GeoVisionary as a vital management tool for the mining cycle.

Conclusion

VR software such as GeoVisionary can augment many aspects of the management of the mining cycle if the data is of high enough resolution, and there is enough data density to make qualified decisions. However this is not the case in all situations, therefore it cannot completely replace the need for fieldwork, site investigation and where decisions need to be made in real time.

GeoVisionary was initially developed as a virtual reality mapping software for geologists, therefore the tools developed for mapping in GeoVisionary and the ability of GeoVisionary to visualize a large variety of 2D, 3D and 4D data in one environment augments many of the stages in mineral exploration. When combined with digital field mapping technologies, the speed and efficiency at which data is assessed, captured and analyzed increases, as does the safety aspects of field work.

Communication is pivotal in the safe and efficient operation of mine. By using GeoVisionary to combine all of the different types of data and objects into one 3D VR environment makes the understanding of instructions and the transfer of knowledge easier. This will help to mitigate against potential hazards, come to conclusions quicker regarding where and where not to extract minerals, and plan for future extraction and the closure of the mine.

GeoVisionary has also the potential to be effective for managing the long-term monitoring of former mines regarding water quality, gas measurements, and chemical data using live sensor information and visualization. Therefore, GeoVisionary can be used throughout the whole life cycle of a mine for various purposes so that minerals are extracted more efficiently and safely.

Literature

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