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Information System for Large Projects in Underground Space Development

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Abstract

The use of underground space within large projects in underground space development demands a detailed and reliable tool for design and management of the underground world. The concept of a "body information system" BIS by continuation of the general idea of "geografic information systems" in space is presented. The task of a BIS is twofold. First it combines all existing databases on the region as a general source of information for any analyses, dependant on the location. Second it realizes the general task of 3D-visualization.

Introduction

Large projects in underground space development motivated by the continued economic development in the most densely populated cities of the world, having a general look on the population density of major world cities. "Placing facilities underground is a promising method for helping ease land use pressures caused by the growth and urbanization of the world s population" (Carmody&Sterling, 1993).

The motivation might be completely different, such as "Countries worldwide have accumulated high-level radioactive waste by using nuclear materials to produce electricity, to power naval vessels, and to make nuclear weapons. This waste must be safely contained until it no longer poses a significant risk to human health and the environment" (Boyle&Rowe, 1999). "Engineering decisions related to large rock engineering projects such as underground facilities for radioactive waste storage, caverns of power plants etc. bear high level of responsibility" (Postolskaya et al., 2001).

The global trend of using underground facilities initiate a twofold discussion. On one hand, benefits and drawbacks of underground facilities are opposed, on the other hand the possibilities of alternative locations or types of construction are taken into account.

The benefits and drawbacks of underground facilities can be subdivided in the major issues (Carmody&Sterling, 1993) of physical and institutional issues, life cycle cost and social issues. Therein, the potential drawback of for example uncertain geology in the location indicates the need of information on the underground as much as possible.

"In order to enable decisions in rock engineering projects and to ensure them, all existing information on the surrounding has to be taken into account. The task to gather information results in the need to organize it, in order to be able to use it in an adequately form" (Jarosch et al. 2002).

Any specific project in underground space development will start by the general task to find the suitable location, followed by the discussion of building alternatives. Both aspects are directly influenced by the character and quality of the underground. Special tasks demands for special conditions on the surrounding.

The information depends on the location. The location has to be specified in the space.

Sampling and analyzing as well as visualizing space-depending information is performed using sophisticated "geographical" information systems GIS. In these information systems, any analysis can be performed as a function of the actual location. "For one point definitely defined by its coordinates on the surface we see the first time combined all available information of any type" (Jarosch et al. 2002).

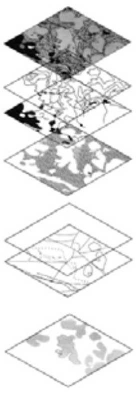


Figure 1. Layers represented in GIS for the near-surface portion of the rock/soil mass at a potential site (Postolskaya et al., 2001); http://www.gis.com/

The old adage "better information leads to better decisions" is true for GIS. A GIS is not just an automated decision making system but a tool to query, analyze, and map data in support of the decision making process (http://www.gis.com/whatisgis/whyusegis.html).

The restriction of the atrributes into account to be given "in topography", which means on the surface of the earth is hidden, when speaking of some sort of 3D-visualization approaches. The 3D-visualization within GIS means the representation of a 2D-surface in the 3D-space, in order "just to have a look on". 3D-objects are introduced by extruding the 2D-projection up or down from a given level. "The ArcView 3D Analyst extension for ArcView GIS of ESRI has finally opened the door to implementation of three-dimensional databases on the desktop in an ESRI-based GIS environment. Three-dimensional databases have been created for a nuclear waste repository and for mining projects" (Elroi, 1999).

"The special character of the task of engineering decisions related to large rock engineering projects implies more, i.e. the extension of the restricted 2d-surface to a general 3d-space" (Jarosch et al. 2002). Therefore the common geopgraphical information system GIS has to be enlarged to a **3D-body information system BIS**. Both the synthesis and the analysis of the BIS are to be developed. Furtheron the special task of visualizing the solid 3d-body has to be discussed.

Retrospection

Geopgraphic Information Systems (GIS) are developed and used since more than 20 years, collecting any available information on a site in a database.

"Whereas even in 1998 during the international workshop on the rock mechanics of nuclear waste repositories in Vail, Colorado GIS did not yet appear at all in the presentations of the different countries programs, GIS start today more and more to play the role of decision support systems, which enable comprehensive analysis of all available data." " (Jarosch et al. 2002).

"In 2000 GISs come up in the conventional 2d-use during the fourth north-american rock mechanics symposium in Seattle" (Jarosch et al. 2002): "Satellite data is then used in conjunction with GIS to do a geotechnical site characterization. This system of site characterization can eliminate expensive on-site or laboratory sampling and testing of the soil, and can also be used in conjunction with slope stability software to identify slopes at-risk of failure, with relative ease" (Greuer&Young, 2000).

In 2001, the use of GIS is explicitely stated: "Combining the Geographic Information System (GIS) spatial analysis function with an improved Hovland s 3D slope stability analysis model, a new GIS based 3D deterministic model is developed" (Tetsuro, 2001). "This information platform should store, systemize in place and time and supervise numerous spatial data related to geology, structure elements, sensitive points and zones of environmental and structural failure risk and restrictions on structure behavior" (Postolskaya et al., 2001) . "GIS applications start to be widely used in different aspects of geotechnical engineering" (Greuer&Young, 2000), especially in "projects of underground facilities for radioactive waste disposal in deep geological formations of hard rock" (Melnikov et al., 1999).

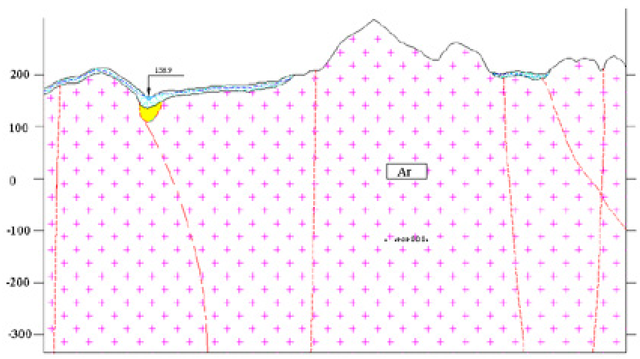
Postolskaya (2001) states: the "implementation of GIS provides unprecedented possibilities of continuous control of the situation at any given stage of construction and operation. Necessary operational improvements and additional software such as graphics packages, etc, may be developed or adopted ...".

A priori information

Any large Projects in underground space development should be accompanied by providing the necessary "a priori" information. "Modelling and site work should be supported by a digital database. There should be a coherent supporting database of all the data, both for scientific reasons and to justify decisions made. It is an essential feature of technical auditing that suitable evidence is required." Hudson (1999).

"The general demand should be and is in fact to know "the most possible" "as detailed as possible" to be able to decide. In fact, our information is sparse and uncertain. Our intention is to optimize the background for decisions. The idea is to sample all available information systematically in one system, and to use this information system to support decisions"(Jarosch et al. 2002).

Whereas there is no doubt on the benefits of "databases of all the data", reality in projects looks different. As we see from the the example of Kola Region, Lovozero, Russia, the available a prior information is sparse, restricted to single profile information (fig. 2) and bore hole results.



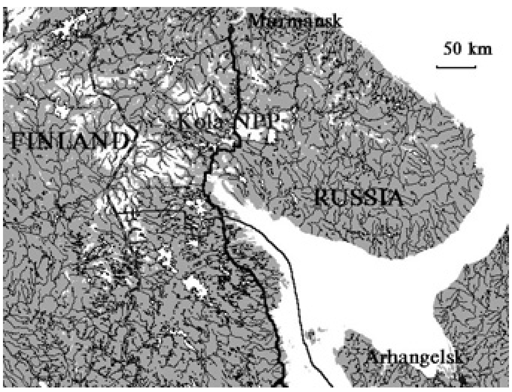


Figure 2. Geological profile in Kola Region, Lovozero, Russia.

"Fundamental regional geological maps are accomplished by geological-geotechnical investigations, resulting in engineering-geological models" (Jarosch et al. 2002). Thereout "creating the engineering-geological model is obviously the most important step in the design of any engineering structure" (Postolskaya et al., 2001) such as radioactive waste repositories.

An idea in mind: concept of BIS

"Typical geological maps, maps of modern tectonics (Melnikov et al., 1999, p.149) or cross sections (Boyle&Rowe, 1999, Fairhurst, 1999) contain a lot of information on the surrounding, but the more complex this information is, the more difficult the task may be to take all these details into account when working on the project, i.e. planning new facilities" (Jarosch et al. 2002).

"Input data such as cross sections defines the need of some "body information systems (BIS)" with locations given in space. One s mind has to be broaden from the (single) upper surface of the earth to its complete body. The resulting 3d-information system will deliver the necessary boundary values for any mechanical problem and last not least the support to any decision on critical underground facilities for radioactive waste storage"(Jarosch et al. 2002).

To enlarge the functionality of a 2d-GIS to a 3d-BIS as a (new) body information system enables should enable the same analysis as in GIS dependent on the location, with space dependent formulation of a special point as "volume element" VE and a layered variety of manifold attributes for this VE.

Actually, the body information model does not yet exist ... the first task will be to put information "in" a suitable data structure provided using the well-known a-priori information of 2d-profiles and assumptions for their prediction in space.

Again the demand to "have a look on" does exist, but "looking" on a solid body not only from outside implies the special task of adequate visualization. To take information "out" of the BIS means to give "spots" from inside the body by cutting the body (resulting in well-known profiles), which are again 2d as a "spot" from inside along a given path. The formulation of adherent representation tasks is the generalization of path cutting, resulting in a

superpositioning of information levels, which will allow any combined analysing.

For example, information type 1 may be the geological structure, whereas quiet different

information type 2 handles with some subground construction i.e. a tunneling system. Any more available information type should be added. The superposition of arbitrary information types allows may be unexpected the answering of elementary problems such as the question on the location of an intersection of 2 tunnels or on the geological formation in this place.

The main point is, that their is a superposition of a manifold of information levels, which is valid in space.

Mathematical formulation and data modelling

To put information "in" i.e. building up the BIS means interpreting data sources such as profiles, combined with assumptions on the profile-continuation in space, and adding CAD-models of the future subground facilities as well as measured profiles.

Generally, these different components of information are given in different scales.Their coordinates are related to three different types of coordinate systems:

1. world system with coordinates (x,y,h)
2. profile system with coordinates (s , h)
3. object system with coordinates (x , y , Δ h)

with:

s ... distances along the given profile, measured from a starting point up to a point of interest

h ... absolute hight in the superior world system

x,y ... 2D-location in the superior world system

x ,y ... 2D-location in the subordinate object system

Δ h ... relative hight in the subordinate object system

As an example for an object system, a 3D FEM mesh for the portion of two parallel tunnels is given in fig. 3.

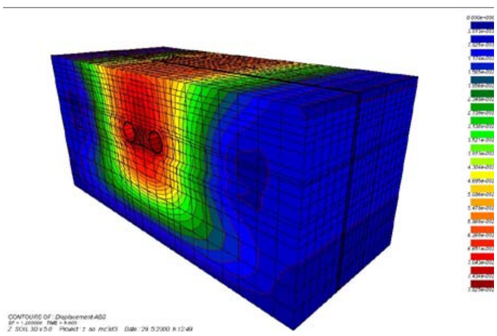


Figure 3. 3D FEM mesh for the portion of two parallel tunnels (Postolskaya et al., 2001)

The profile system has to be accomplished by some information on the positioning of profile in the world system, its orientation, given by an azimuth formulated by a starting point and end point of the profile in coordinates of the world system. Furthermore, the absolute positioning of the object system in the world system has to be given in form of suitable pass-points.

The transformation of the object system as well as the profile system into the world system by a common 3D-rotation in general gives a unique interrelation between the different components and answers any question on special aspects such as intersections and so on. Out of the characteristics of the special task here, the general 3D-rotation will be reduced to a simple z-rotation plus a translation. As far as pass points are given in the object system and/ or the profile, a scale may be added to accomplish a correct transition.

In this way, any measuring point given in the world system is immediately correlated with the existing body-information-system thus introducing any measuring result in the BIS.

Orthogonal 3D-systems provided, the suitable description of the aforementioned systems answers any question on existing relations. In the BIS, points of interest are no longer 2D-locations (x,y) as in GIS, but have to be given as 3D-coordinates (x,y;h).

The attributes attached to a special point of interest are free to be choosen. There interpretation in form of a spatial analysis and their visualization have to be redefined analogous to the well-known 2D-procedure of the established GIS-analysis.

Tools for analysis and visualization

The demand for analysis and visualization may be described effectively by the situation of planning a large projects in underground space development. Two tunneling profiles may be given, by the profile itself such as i.e. a horseshoe section tunnel and a circular section tunnel (Carmody, 1993) and by its orientation in space. Both profiles are supposed to be vertical. Furthermore the geological structure as far as known in the area of interest is given by at least one or several profiles.

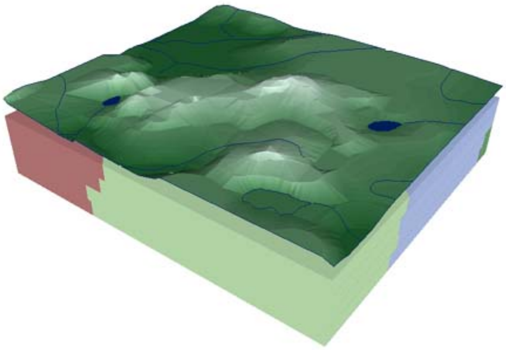


Figure 4. BIS by continuation of profile information on geology and given topography.

The inner structure of the solid body is hidden, looking from outside on its predicted structure. The task of analysis is in principal "to look inside" at points of interest, by simply cutting along an arbitrarily placed plane or more general along a free-choosen cutting path, resulting in a specific "enlarged" profile.

The information of the free profile cutting is completely given in the BIS, the tool has to be developed by simple interpolation the given information and visualizing all given levels of information. This time, the "sheets" of information are given in space. This multidimensional problem is unique having in mind our "old fashioned" thinking reduced to a plan when using maps or profiles.

Layered information in 3D-space demands for suitable visualization alternatives. With the BIS in the background, any profile is uniquely defined especially this of the geological profiles, the two tunnel profiles are element of. Both the physical surrounding of the starting tunnel profiles and any arbitrarily choosen further profile are given. Special attention has to be payed to the intersection profile of the two tunnels, as far as an intersection may exist. The description of the intersection is uniquely given by the positioning of the starting profiles and the orientation of the tunnels in space. The information on the existence of an intersection or the computation of the minimal distance of the tunnel axes is analytically given, as well as its orientation. Thereout, the visualization of the intersection in the geological structure results immediately (see table 1).

a priori information BIS with continuation of the geological structure in space + starting profiles of the tunnels

+

absolute orientation of the starting profiles in space

+

absolute orientation of the axes in space

⇓

computational analysis

analytical computation of the absolute orientation of the intersection

or

analytical computation of the minimal distance of the axes in space

and

analytical computation of the form of the intersection

⇓

visualization

1. geological structure in the starting profiles of the tunnels
2. geological structure in *any arbitrarily choosen profile*, especially the intersection profile

3. form of intersection.

Table 1: Synthesis and analysis to put information "in" and get information "out" of a BIS

Conclusions

The concept of a "body information system" BIS, resulting out of actual discussions of practical geotechnicians, enables the combined analysis and visualization of measurements with different types of sensors in different locations in space. Both the synthesis and the analysis of the BIS is discussed as the logical continuation of the 2D GIS for the surface "topography" in 3D space. In a first step, the synthesis results in an information system, which has to be iteratively improved to a sophisticated space-model. The highlight is the thereout resulting possibility to predict the general behaviour such as spatial intersections out of fixed starting values and the tool of general 3D-transformations.

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